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Runoff Sediment Yield Modeling and Development of Management Intervention Scenarios, Case Study of Guder Watershed, Blue Nile Basin, Ethiopia

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Abstract

Modeling Surface runoff and sediment loading provides important planning tools that can be used in management of land and water resources which can be used in the understanding of dynamic processes and prediction of the existing processes which have advance implication in the understanding of physical and biological processes of watershed.The objective of the study is to model runoff-sediment yield for Guder Catchment, characterizes the runoff from catchment and associated sediment yield, to evaluate spatial distribution of sediment source areas and identify hot spot areas, to assess the impact of different catchment management interventions on runoff and sediment yield and finally develop appropriate management options to control soil erosion and sedimentation problems in Guder watershed by using physical based SWAT model. SWAT model were calibrated and validated at Guder gauging station for both stream flow and sediment yield yielding reasonable results in monthly time step. The 17 years simulation result indicates that the simulated annual average suspended sediment yield by SWAT model was 4,842,000 ton/yr, which is 7.5 t/ ha /yr. The model prediction verified that about 9% of the watershed is erosion potential area contributing high sediment yield exceeding the tolerance limit (soil formation rate) in the study area and about 25% of the watershed area has high potential for soil erosion which produces above 10 ton/ha/yr sediment yield of the watershed. The simulation results showed that applying filter strips and parallel terrace/stone bunds scenarios reduced the current sediment yields by 48% and 53% respectively from the existing condition scenario both at the sub basins and the basin outlets i.e. sediment yield reduced to 3.908 t/ha/yr and 3.54 t/ha/yr by using filter strip scenario and conservation structure scenario respectively. Generally, studies like this in quantifying the total volume of runoff and sediment yields are urgently required for better land and water resources planning and management purposes.

Keywords: Modeling; Sediment yield; Runoff; Guder watershed; Management interventions

Introduction

The rates of soil erosion and land degradation in Ethiopia are high due poor land use practices, improper management systems and lack of appropriate soil conservation measures. Ethiopia loses about 1.3 billion metric tons of fertile soil every year and the degradation of land through soil erosion is increasing at a high rate which calls for immediate measures to save the soil and water resources degradation of the country [1].

About 85% of Ethiopian highlands provide nearly 85% of the flow to the main Nile Basin [2]. The land and water resources of the study area (Guder watershed) are adversely affected by the rapidly growing population and the rising demand for cultivated land. Moreover, intensive cultivation of annual crops has caused serious erosion problems in the area, resulting in soil nutrient depletion or soil fertility reduction [3]. This process, together with the increasing population, has aggravated degradation in the area resulting in on-site soil erosion and off-site heavy sedimentation.

Runoff and sediment accumulation is one of the most important factors in the planning of a dam, because uncontrolled soil erosion and land degradation resulting in heavy sediment transport in streams and rivers has caused significant reduction of the capacity of reservoirs and studies have shown that in Ethiopia billions of tons of soil are lost annually; particularly in the Ethiopian highlands soil erosion is a major problem with an estimated loss of 16-50 ton/hectare/year [4].

Spatial and temporal organization emerges from a large number of physical and biological processes operating at the catchment scale. Many landscape modelers remain stuck at lower levels, and the catchment scale models required for management and scientific understanding are either not available or are too complex for meaningful use. Emphasis should now be given to either directly modeling the high level, or emergent, properties of catchments, or producing models that can reproduce these high-level properties [5].

Different hydrological model uses certain application, and the choice of a suitable model relies heavily on the function that the model needs to serve. For this study SWAT model is selected due to its computational efficiency, data requirement, level of application. SWAT watershed model is one of the most recent models developed by the USDA-ARS to predict the impacts of land management practices on water, sediment and agricultural chemicals yields in watersheds with varying soils, land use and management practices over long periods of time [6]. There are various criteria which can be used for choosing the proper hydrological model for a specific problem. The model was tested for prediction of runoff and sediment in Abbay with satisfying results and good performance watersheds of Abbay basin [7-10].

This study emphasizes the total amount of sediment yield from the Guder watershed and rate of reservoir sedimentation (Karadobi dam site) which will be constructed at the downstream of Guder River and the overall concept of sustainable sediment management that will benefit future generations as well as our own. Research conducted by Fetene [8] has shown that the study basin (Guder basin) yields the highest Sedimet yield of all the basins of Abbay basin. Therefore, it is necessary to quantify the potential runoff generated and sediment yield, apply different catchment intervention scenarios so as to reduce sediment yield and runoff from the catchment.

The finding of this research revealed out of the total 35 sub basin 9 sub-basins produce average annual sediment yields above 10 ton/ha/yr and the highest loading is from found in North Jeldu and Ambo woreda's. The spatial map shown in Figures 1-3, allows us to identify sub catchments which are producing high sediment yield loading. The impact of BMPs at the selected critical sub basin level showed spatial variability on sediment reduction from baseline conditions as is shown below in table below. The sediment reductions for selected critical sub basin ranged from 30.4% to 90.6% under filter strips scenario, 14.6% to 94.5% under conservation structure (parallel terrace and stone bunds) scenario. That is the mean annual sediment was reduced to 3.908 t/ha/yr and 3.504 t/ha/yr by using filter strip scenario and conservation structure scenario respectively.

Study Area and Data Used

Guder river is located at altitude and longitude of 9° 55′N, 37° 56′E in the central Ethiopia. The river flows from the south to the north and has its outlet to the Abbay River. The Guder basin borders with the Muger Basin to the east, the Awash Basin to the south and the Fincha River Basin to the west. Tributaries of the Guder include the Dabissa and the Tarantar. The Guder has a drainage area of about 7,011 square kilometers in size (Figure 1).

The climate of the study area is classified as uni modal characteristics with one rainy and one dry season. The rainy season extends from May to October and dry season from November to April. In period (1981 - 2008) shows that, a high concentration of rainfall occurs in July and August. The mean annual temperature of the Guder watershed ranges between 6.5°C and 30°C. Some of the major tributaries of Guder catchment include the upper side of the watershed which collects surface runoff from Huluka, Bello, Fetto, Melke and Indiris in the middle part of the watershed which collects surface runoff from dabis and in the dawn stream part tinishu Guber and Tiliku Guber contributes the main Guder River.

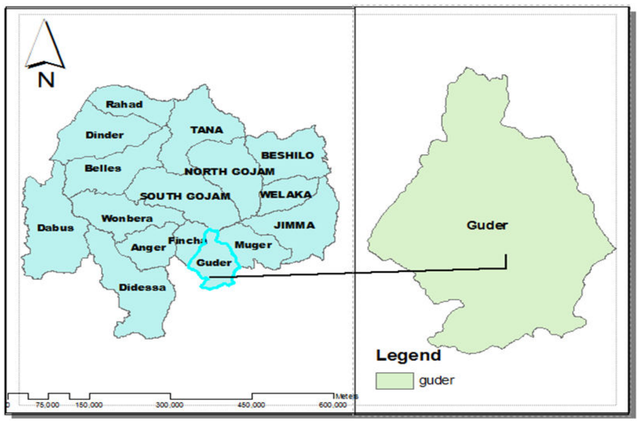

Figure 1: Location Map of the study area.

All the data were analyzed as per the model requirement, the model was set up and run depending on the required in put in addition time series data was checked for different tests (homogeneity, stationarity, no trend, consistency and complete with no missing data). Because erroneous data resulting from lack of appropriate recording, shifting of station location and processing are serious because they lead to ambiguous results that may contradict to the actual situation.

The meteorological data required were: daily precipitation, daily maximum and daily minimum air temperature, daily solar radiation, daily wind speed, and daily relative humidity. If any of these data was not available, which is very likely, SWAT can generate data using weather generator. Precipitation and temperature: the daily precipitation and temperature of all stations were prepared in dbf format. Solar radiation, relative humidity, and wind speed data were available only for principal station (Ambo). These data for the rest of the stations were generated by SWAT (these data consist of monthly average values of all the values required by the SWAT model in order to generate daily value).

Six meteorological stations were selected which were found in and around the study area (Table 1). The relevant time series data used for this study includes daily rainfall data, stream flows, suspended sediment yield, temperature (minimum and maximum), relative humidity, wind speed, solar radiation and Spatial data (DEM, soil map, land use map). Data were collected from the MoWIE and Ethiopian Meteorological Agency.

The infilling of missing flow data in this study is accomplished by using regression method by taking the correlation between the available four (Bello, Indris, Fetto, Debis) gauging stations (dry and wet season data periods for each station were conducted independently for different time periods). In similar way with the meteorological data's the assessment of data quality test for hydrological data (stream flow) of the used gauging stations of Guder flow data's for absence of trend, instability (stationery-test), absence of inconsistency and absence of inhomogeneity has been checked.

Lack of available sediment data is experienced in our country as a whole and it was quite difficult to assess the watershed modeling with the scarce data. An option to solve this kind of scarcity is by generation of sediment rating curve (developing exponential relationship between river discharge and sediment concentration for the existing data) but it

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might increase uncertainty which is not as equal as the real observed values. Sediment rating curve was developed in order to generate continuous daily sediment data from the available sediment concentration at Guder gauging station.

ID	Station	Long	Lat	RF	Max Temp	Min Temp	Relative Humd	Wind Speed	Sunshine Hour	Record Length (year)	Source
1	Ambo	371385	992846							23	ENMA
2	Ijaji	315309	993064							23	ENMA
3	Gedo	362597	995087							23	ENMA
4	Guder	364781	990656							23	ENMA
5	Jeldu	397853	1024836							23	ENMA
6	Teji	430721	976116							23	ENMA
7	Tikur Enchini	351530	975220							23	ENMA

Table 1: Data Type, Length and source of meteorological data. Where: ENMA: Ethiopian National meteorology Agency; stands for availability and × Not available.

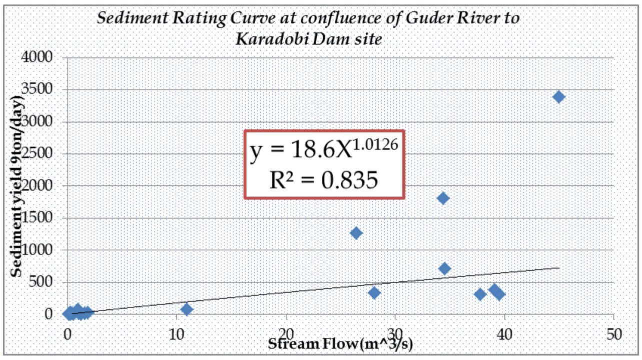

Figure 2: Sediment rating curve at the confluence of Guder near karadobi dam site.

Methodology

Data is the crucial input in hydrological modeling. Data preparation, analysis and formatting to suit the required model input is important and has influences on the model output.

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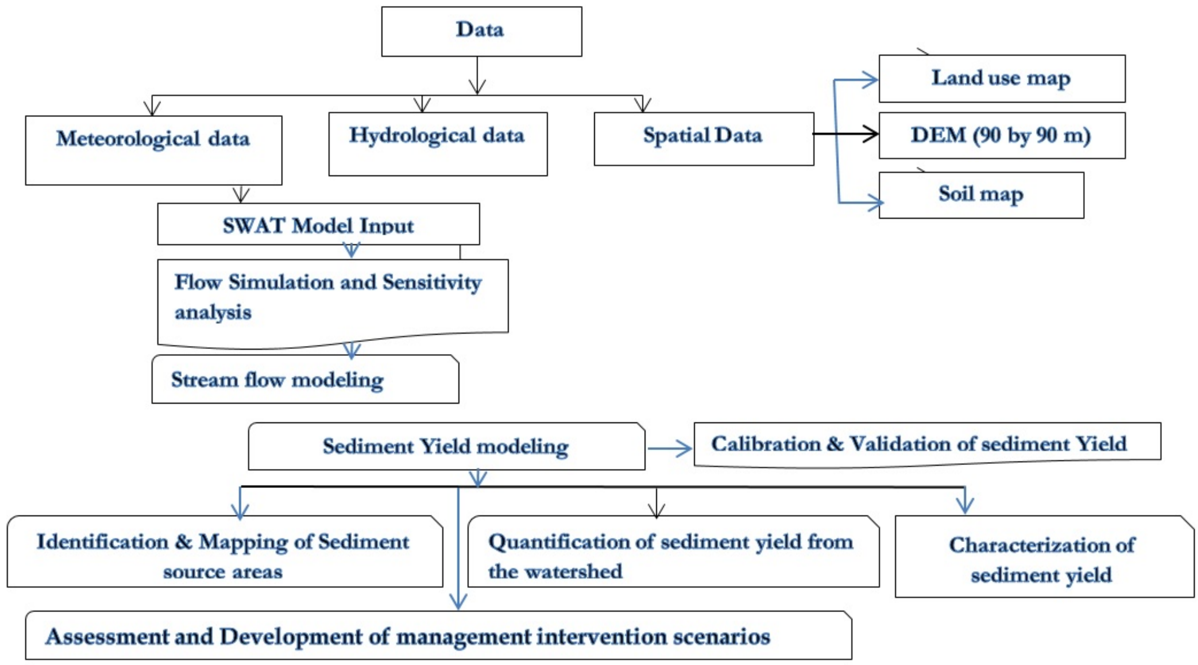

Figure 3: General Conceptual Frame Work of the study.

Model algorithm specification

Prior to the model is set up and inputs are added, the computation of required water balance components for the simulation on the algorithm embedded in SWAT model should have to be identified. The following computation algorithms have been used for this study:

1. SWAT CN method of runoff computation (models' occurrence of runoff from infiltration excess processes)

2. Channel water routing method in the reaches (variable routing)

3. Potential evapotranspiration by Hargreaves method

4. Multiple HRU definition (10%, 10% and 20% for land use, soil and slope domination to which land use percentage over the sub basin, soil over the land use and slope class percentage over the land use respectively were adopted in these studies during HRU definition.

5. Sensitivity analysis was conducted by setting the simulated scenario as a default simulation and the method of sensitivity analysis which was performed in this study was the built-in SWAT sensitivity analysis tool that uses the Latin Hypercube One-factor-AT-a-Time (LHOAT), the analysis was performed by using the observed flow and sediment yield data at the Guder gauging station (considered outlet).

Catchment management intervention scenario modeling

Watershed management intervention involves the development of system for management and utilization of land, water and vegetation resources that are economic, productive and sustained in the long run. Agronomic (vegetative) and physical (Engineering measure are the most common [11,12].

Implementation of watershed management plan provides the necessary measures for protecting the catchments (or watersheds) of Guder subasins. Absence of such a plan and inappropriate development in watersheds can lead to widespread soil erosion and therefore siltation of the reservoir. This can reduce the useful life of Karadobi proposed dam scheme. Therefore, In the process of planning water resource project, practical measures to prevent the occurrence of soil erosion are imperative. Therefore, in order to use model as a tool for analyzing the effects of different management measure for runoff and sediment transport in the study area, the following catchment management scenarios were developed. This scenario involves the introducing of Best Management Practices (BMPs) and the parameters for these scenarios were incorporated in the management input data.

BMPs that have been used in this research are:

1. In Scenario 1, when the watershed existing conditions is considered

2. In Scenario 2, when different width of filter strips was placed on all agricultural HRUs that are the combination of dry land cropland, all soil types and slope classes since the effect of the filter strip is to filter the runoff and trap the sediment in a given plot [13]. Thus, for this study 5 m wide filter strip is adopted.

3. In Scenario 3, when parallel terraces with different slope length and stone bunds were placed on agricultural HRUs that are the combination of dry land cropland, all soil types and slope classes. Thus, for this study we used 40% reduction of slope length.

Results and Discussion

Stream flow modeling

Flow sensitivity analysis was carried out for a period of 17 years, which includes both the calibration period (from January 1, 1988 to

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December 31, 2004) and two year of warm-up period (from January 1, 1988 to December 31, 1989). The sensitivity result about eight Parameters were taken as governing parameters which were believed to have effect on the simulated values are considered for calibration. The sensitivity analysis result that the model withdrawn is as shown in the Table 2.

Parameter Code	Rank	Mean Sensitivity	Category of Sensitivity
Alpha_Bf	1	0.141	High
Canmx	7	0.0464	Medium
Sol_Awc	8	0.0461	Medium
Cn2	5	0.0516	High
Revapmn	6	0.0496	Medium
Gwqmn	3	0.0758	High
Esco	2	0.0985	High
Sol_Z	4	0.0547	High
GW_Revap	10	0.0254	Medium
Blai	9	0.0451	Medium

Table 2: Sensitivity analysis result for stream flow in Gudr Watershed.

Considering the availability of reliable data, spatial consideration (areal extent covering high drainage area) Guder the gauging station was selected and used as calibration point. The final calibrated flow parameters for Guder watershed are presented below (Table 3).

Parameter	Range	Initial Default Values	Calibrated Value
Alpha_Bf	0 - 1	0.048	0.056
Cn2	_+25%	Default*	+24%(Added)
Esco	0 _ 1	0.95	0.9
Gwqmn	0 - 5000	0	4500
Revapmn	0 - 500	1	250
GW_Revap	0.02 - 0.2	0.02	0.18
Sol_Awc	_+25%	***	+17% (Added)
Sol_Z	_+25%	***	-23% (Reduced)

Table 3: Result of final calibrated flow parameters for Guder Watershed.

The hydrograph (Figures 4 and 5) fluctuation of stream flow was observed during calibration and validation periods in both low and high flow seasons, this undulation might exist due to the models low capability to capture peak rainfall event, the data quality's occurred during filling missed data's and error during measurement records. During the calibration period the model slightly underestimates stream flow in the months August and July of years 1991, 1992, 1993, 1994, 1995, 1996, 1998, 2000 and 2004 and overestimates during low flow seasons.

Flow validation was carried out from January 1, 2005 to December 31, 2008 without further adjustment of the parameters of flows. The hydrograph for the validation period of the observed and simulated flow is in a monthly base estimation. The hydrograph of validation period was as presented in above Figure 5. A good agreement between measured and simulated monthly stream flow at Guder gauging station was demonstrated by correlation coefficient (R2=0.75) Nash-Sutcliffe model efficiency (NSE=0.73) and percent bias (PBIAS=_12.87%) for calibration period and R2=0.81, NSE=0.71 and percent bias (PBIAS=12.4%) for validation periods (Table 4).

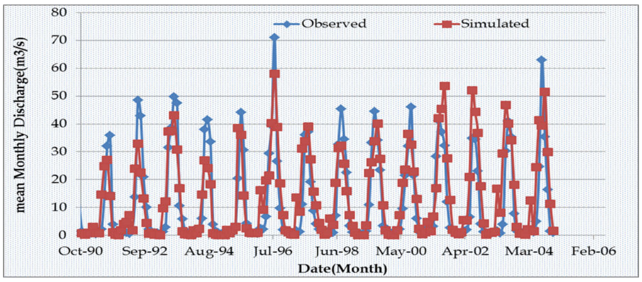

Figure 4: Calibration results of average monthly observed and simulated flow hydrograph (1990-2004).

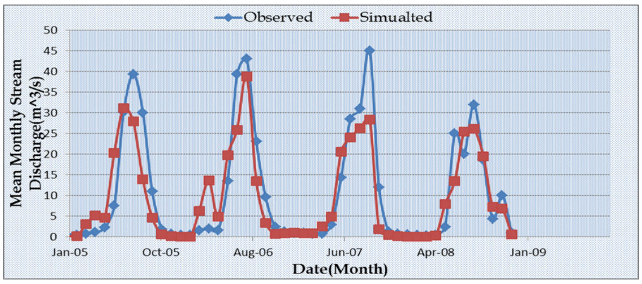

Figure 5: Validation results of average monthly observed and simulated flow hydrograph (2005-2010).

Monthly time step simulation	Mean Monthly Stream flow(m^3/s)		Model Performance		
	Observed	Simulated	R^2	NSE	PBIAS
Calibration period (1990-2004)	11.94	13.48	0.75	0.73	_12.87%
Validation period	10.77	9.54	0.81	0.79	11.40%

(2005-2009)					

Table 4: Calibration and Validation result statistic for monthly measured and simulated Stream flow.

Sediment yield modeling

Sensitivity analysis was carried out for sediment to identify parameters that affect sediment yield for the period (from January 1, 1988 to December 31, 2004) and two year of warm-up period (from January 1, 1988 to December 31, 1989). The sensitivity analysis result that the model withdrawn is as shown in the Table 5.

Parameter Description	Parameter Code	Rank	Mean Sensetivity	Category of Sensetivity
Channel Cover factor	Ch_Cov	7	0	Negligible
Channel Erodiblity factor	Ch_Erod	7	0	Negligible
Channel sediment routing	Spcon	2	0.213	High
Sediment re entrained in channel routing	Spexp	3	0.0327	Medium
USLE-Cover and management factor	Usle_C	7	0	Negligible
USLE-Support practice factor	Usle_P	1	2.92	very High

Table 5: Result of sensitive analysis of Sediment parameters in Guder watershed.

Like Flow, sediment calibration for the Guder watershed by comparing monthly model simulated sediment load against monthly measured sediment from Guder gauging station for the period January 1, 1990 to December 31, 2004. Also, two year (January 1, 1988 to December 31, 1989) was skipped for model initialization (warm-up period).

The final calibrated sediment yield parameters (Table 6) for Guder watershed that yields an acceptable statistical performance (calibration and validation) in Table 7 can be used for further investigation of the watershed (Figures 6 and 7).

Parameters		Default Values	Allowable Range to change	Adjusted Parameters value
Spcon		0.0001	0.0001-0.01	0.008
USLE_C	AGRC	0.01	0.001-0.5	0.0065
Spexp		1	1 to 2	1.02
USLE_P		1	0 - 1	0.6
BIOMIX		0.2	0 - 1	0.15

Table 6: Final Calibrated Sediment Yield Parameters for Guder Watershed.

Monthly Time step	Over Year Mean Sediment Loading(ton/yr)		R^2	NSE	PBIAS
	Observed	Simulated			
Calibration (1991-2000)	88038.54	98900.2	0.8	0.78	_12.34%
Validation (2005-2008)	103627.81	88868.7	0.84	0.81	14.24%

Table 7: Calibration statistics of observed and simulated Sediment load.

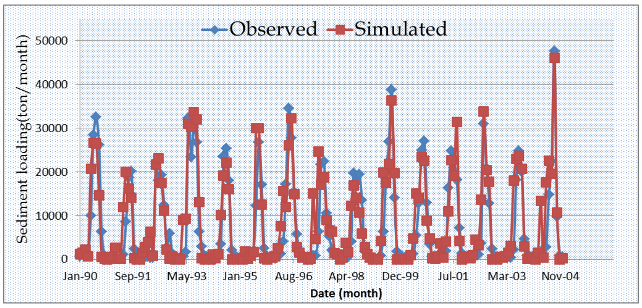

Figure 6: Calibration results of monthly Observed and simulated sediment yield hydrograph.

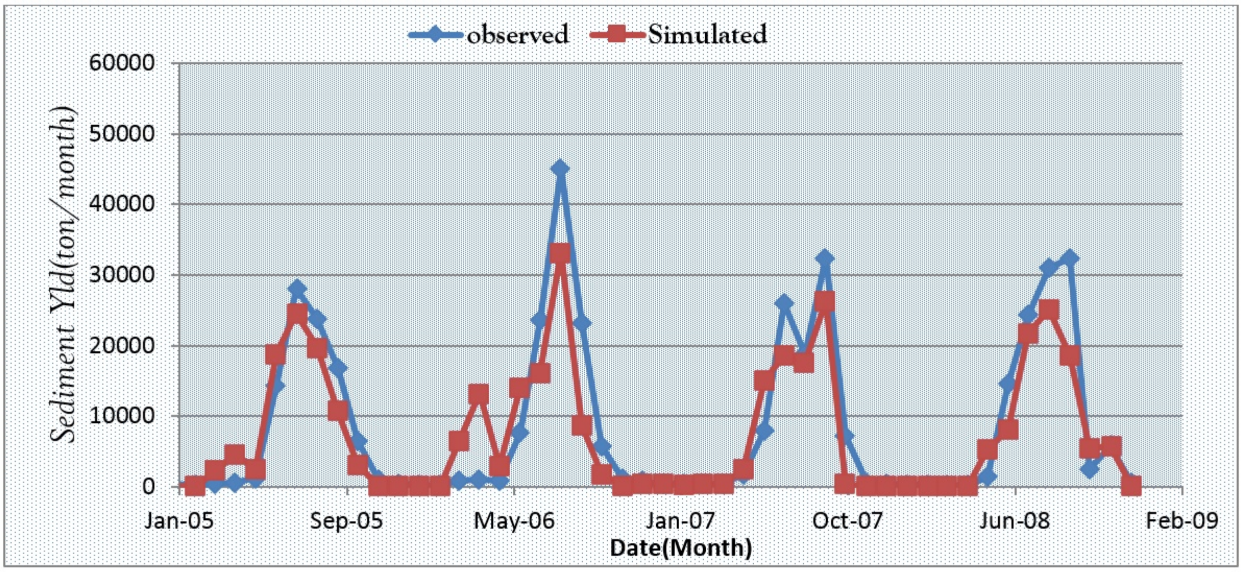

Figure 7: Validation results of monthly Observed and simulated sediment yield hydrograph.

Identification and mapping of runoff and sediment source areas

Once the model (SWAT) was calibrated and validated, it was run for a period 21 years (1988 to 2008), then the overall simulated output can be used for further application (the catchment can be represented for any hydrologic response) and sediment source areas were identified Watershed.

The contribution of average annual sediment yield from each sub-watershed ranges from 0.01 ton/ha/yr to 25.6 ton/ha/yr and similarly the average annual runoff from each sub-watershed ranges from 17 mm to 609.6 mm during the period of from (1988-2000).

Based on the model's prediction, runoff and sediment yield in the sub watershed varies from HRU to HRU depending on the type of soil, slope and land use in each HRU. Most of the extreme erosion was observed in the cultivated land (Agriculture) and low erosion was observed in the deciduous forest covers. Severe erosion was dominant in sub basins 1-8,11,12,15,16,18,19,20,22,23,28,32,33,34 and 35. High erosion was dominant in sub basins 3, 17, 19, 24, 27 and 30. The highest erodible Sub basins having annual surface runoff above 400 mm were found in Jima Rare, Jeldu, Abuna Gindeberet, Tikur Enchini, Tokko Kutaye and Elifata.

Assessment of the spatial variability of Surface runoff and sediment yield is useful for catchment management planning and identifying the most erodible catchment. The erosion /runoff prone areas in Guder Catchment are shown in Figure 8.

A study of soil formation rates in different agro ecological zone of Ethiopia indicates that the range of the tolerable soil loss level for the various agro-ecological zones of Ethiopia were 2 to 18 t/ha/yr [11]. Based on these, classes were assigned depending on their annual average sediment yield loading per coverage; the map was reclassified into four major categories of soil erosion hazards region i.e. low, moderate, high and severe erosion conditions (Table 8).

S. No	Woreda	Sub basins found	Average Annual Runoff (mm)
1	Abuna Gindeberet	5	429.8
2	Jima Rare	15,22	470.4
3	Hababo Guduru	1	609.6
4	Gudru	8,9,10,13,14,16	117.1
5	Wonchi	Half in 32,35	-------
6	Ameya	35 (half)	-------
7	Elifata	23	604.7
8	Tokko Kutaye	27,29,32	265.8
9	Dendi	Half in 33 and 31	
10	Tikur Enchini	34,35	485.9
11	Chelia	28	387
12	Midakegni	12,17,21,26	181.6
13	Ambo	25,24,30,31,33	153.4
14	Jeldu	11,18,19,20	326.5
15	Ginde Beret	2,3,4,6,8	306.1

Table 8: Simulated Annual average surface runoff generated from Guder Woreda's.

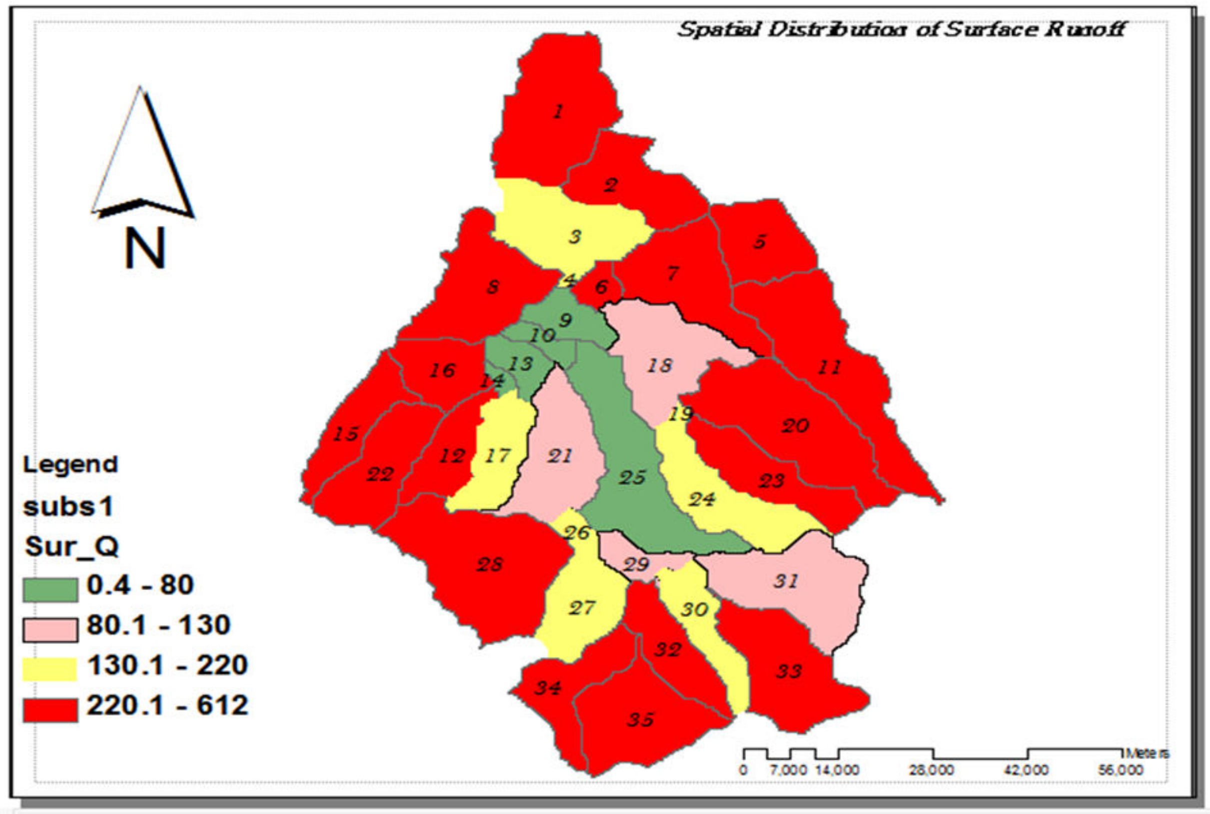

Figure 8: Spatial Distribution SWAT simulated annual surface runoff in Guder watershed.

The highest sediment yield sub basin areas are those which are covered with cultivated land (Agriculture). The yellow and red highlighted areas of the watershed are potential areas which are sucepible for erosion and sediment yield.The HRU distribution for the selected sub basins clearly indicates the land cover (Agriculture) is the major controlling factor for runoff and sedimnet potential areas.

The spatial distribution of sediment indicated that, out of the total 35 sub basin 9 sub-basins produce average annual sediment yields above 10 ton/ha/yr and the highest loading is from found in North Jeldu and Ambo woreda's. The spatial map shown in Figure 9 allows us to identify sub catchments which are producing high sediment yield loading.

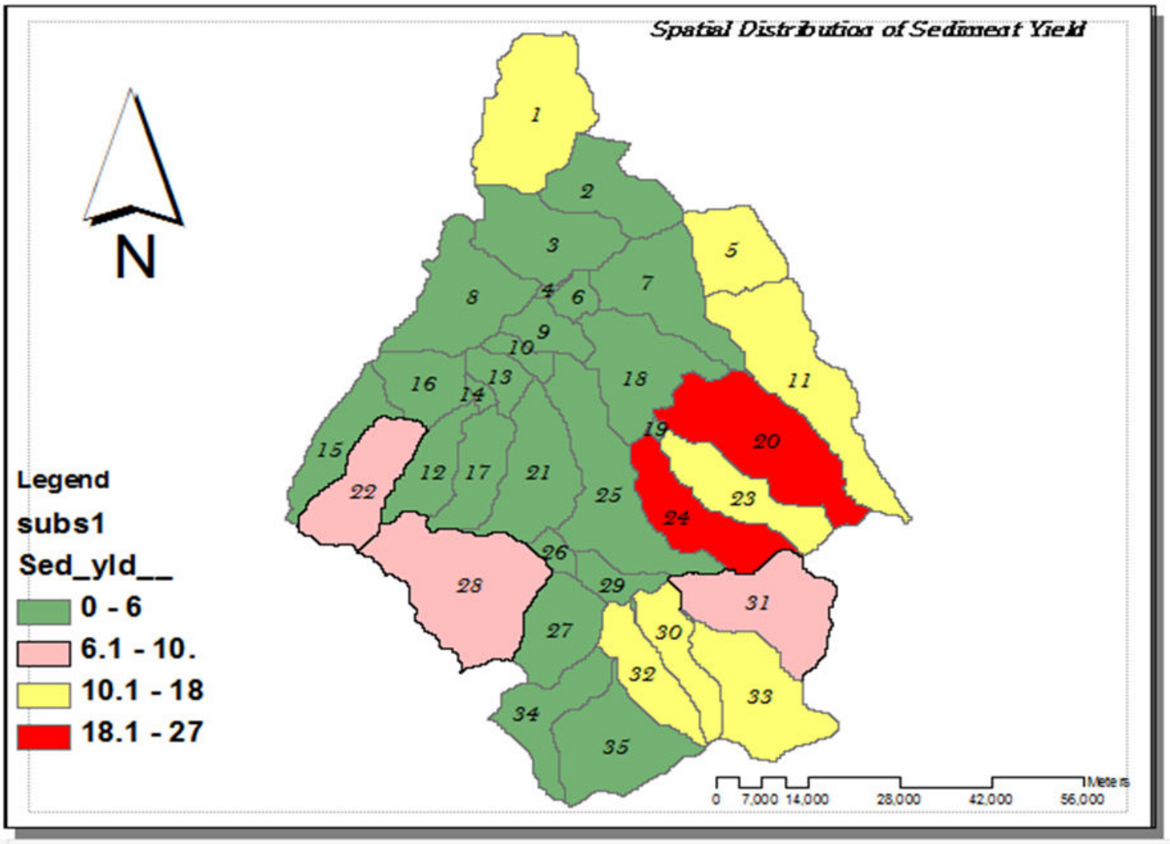

Figure 9: Distribution of SWAT simulated annual sediment yield in sub basins of Guder watershed.

From the total sediment contribution bed load contibutes 10 to 15% of suspended load. Taking 12.5% contiribution of bedload, the total mean annual simulated sediment loading from the Guder Watershed is 8.44 ton/ha/yr.

Fetene et al. [8], from the 16 sub basins of Abbay Basin the highest sediment yield is from Guder, North Gojjam, Jemma, South Gojjam, Welaka and Finchaa sub basins respectively. The result obtained from this research has made reasonable agreement with this study. Land use /land cover was found the influential parameters for sediment yield rather than the existing surface runoff and precipitation.

Efforts were made to know the potential sever and high sediment source areal coverage of Guder watershed and the result has shown that 9% of the watershed has excceded the tolearbe range (more contribution form Jeldu and Ambo woredas), 25% of the wastershed was exposed in high sediment yield and about 65% of the watershed was in moderate and low level. From this result it is concluded that mitigation measure for prevention of severe erosion and conservation by develop appropriate management option for those selected critical sub watersheds (sub basins) should have to be taken (Table 9).

Range of Severity to sediment	Sub basins	Areal Coverage	Percentage
Low	2, 3, 4, 6, 7, 8,9,10, 12, 13, 14, 15,16,17,18,19, 21, 25, 26, 27, 29, 34 and 35	3321.12	51%
Moderate	22, 28, 31	911.92	14%
High	1, 5, 11,23,30,32, 33	1638.52	25%
Severe	20, 24	584.36	9%

Table 9: Percentage of Severity to Sediment for Guder Sub basins.

Generally surface runoff and sediment yield had somewhat direct relationships, since the surface runoff is the major detaching power for sediment yield (transport). Most of the sub watershed in the Guder watershed that has generated relatively high annual average surface runoff also produce (generate) relatively high annual average sediment yield as illustrated in (Figure 10), these sub basins show the general

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principles and relationship between runoff and sediment yield. However, in some sub basin this is not true for instance, sub basins (2, 3, 6, 7, 8, 17, 18, 21, 25 and 35) generate relatively high annual average surface runoff potentials but produce (yields) relatively low annual average sediment yield as compared to the other sub watersheds in the Guder catchment. In this sub basins even if, surface runoff which is one of the major factors for sediment yield is relatively high, the sediment yield in the sub watershed is low.

This shows surface runoff alone has no direct impact on the sediment yield. It is due to the land use/land cover factor, slope length and steepness, and soil characteristics are the major factors for low sediment yield in each sub watershed and are expected to highly influential for the sediment yield.

For instance, in the sub watershed No (24), 69.5% of the watershed area is covered by Agricultural land (coded as AGRC) land use with 36% of Dystric cambisols. In this sub basin 44% of the watershed area has the slope above 18% slope class, 25.7% of the watershed area has the slope of 10-18 slope class and the rest of the sub watershed area has the slope of 0 -5 and 18 - 9999 slope classes. In this sub watershed land use is the most dominant factor for high sediment yield production (25.6 ton/ha/yr) and also average annual surface runoff is also relatively moderate with (178.24 mm) that can cause a detaching power for soil erosion (sediment transport).

On the other hand, for the other sub watershed, for instance sub basin No (20), 65.2% of the watershed area is covered by Agricultural land (coded as AGRC) with Dystric cambisols. In this sub basin 30.1% of the watershed area has the slope of 10-18 slope class, 29% of the watershed area has the slope of 18- 9999 slope class. In this sub basin, the average annual surface runoff (611.27 mm) is the highest of all sub basins that generate sediment yield generate 19.9ton/ha/yr, so in this sub basin surface runoff has direct relationship with sediment yield. High surface runoff values do not give high values of sediment yield in all sub basins, accordingly not only the catchment surface run off has an influence or direct effect for high sediment loading but land use / cover is also another contributing factor.

These highest sediments yield sub-watersheds were, hence assigned as the top priorities and were recommended to be considered for the future conservation plans (for scenario analysis). This high sediment yield production in some sub watershed is due to land use land cover factor, gentle slope and soil type effect and in most of sub watersheds high rainfall/ runoff are the major factors for production of high sediment yield. The high sediment yield predicted in this sub watershed may be also due to increasing of intensive cultivation, steep sloping areas, high population pressure, and other environmental problems.

Watershed management intervention impact analysis in guder watershed

As Watershed management intervention involves introducing of best management practices to reduce soil erosion and sediment transport. The SWAT model was applied to simulate the impact of best management practices on sediment yield reduction in the U.S [14].

These best management practices were represented in SWAT model by modifying SWAT parameters to reflect the effect of practice on the processes simulated within SWAT [13]. But, selection of these best management practices and their parameters values are site specific and should reflect the reality of study area.

Past watershed interventions in the area (Guder watershed): In the study area, as the information gathered from Guder basin woreda Agricultural office and visual observation, the study area has already physical soil and water conservation measures such as terraces, cut-off drain, soil bunds, water way, moisture harvesting structure(micro basin and deep trench), Gabion check dams, Gully treatment through biological and physical methods and check dams, these measures were not effective and many land areas have been damaged by runoff and failure of the structures where physical measures were practiced.

As shown in the Table 10 below there exists past interventions made in woreda's of the study sub basins (Guder) found in west shoa, south west shoa and horo Guduru wellega zones) which have shown positive impact on the productivity of land. but those structure are not fully conducted in all kebeles and are not effective due to deliberate action of farmers, improper sizing of distance between bunds, poor quality of work, land occupation by physical measures, water logging problem, inconvenience for ploughing and free grazing were the main cause for destruction of constructed/established physical soil and water conservation measures (source is obtained from field observation and interview with woreda offices).

Sub basins	Annual Average Sediment Loading (ton/ha/yr)	Found In (Woreda)	Areal Coverage (km^2)	Past Intervention in sub basin
1	10.507	Hababo Guduru	343.28	Soil Bund, Hillside terrace, cutoff drain
5	10.844	Abuna Gindeberet	164.96	>>
11	12.938	Jeldu	374.28	>>
20	19.891	Jeldu	369.4	>>
23	13.438	Elifata	192.08	>>
24	25.568	Ambo	214.96	Hill side terrace with trench, terrace planting, Afforestation, physical/biological gully treatment
33	16.063		270.92	
30	14.34		136.92	

32	11.76	Tokko Kutaye	156.08	Soil bund, Fanay-juu, cutoff drain, waterway, moisture harvesting structure (micro basin, deep trench)
Total Area that needs intervention=2222.9 km^2				

Table 10: Past conservation measures taken in selected critical subasins.

For this study, the selected appropriate best management practices and their parameters values were based on documented local research experience in the Ethiopian highlands [15]. In order to use the model as a tool for analyzing the impact of best management practices on sediment yield from critical (high sediment yield) sub watershed, an alternative management scenario analysis should be conducted.

Scenario analysis

Once the model has been calibrated and validated and the results are considered acceptable, the model is ready to be parameterized to the conditions of interest (e.g., to evaluate impact of land use change, management and conservation practices). In this study two management scenarios were considered and simulated to reduce runoff as well as sediment yield of Guder critical watershed. The scenarios used, and the final stated parameters are presented in Table 11.

		SWAT Parameters Used			
Scenarios	**Description**	**Parameter name**	**Input File**	**Calibration Value**	**Modified Value**
Scenario 0	Base line				
Scenario 1	Filter Strip	FILTRW(.hru)	5m	0	5m
Scenario 2	Parallel or Hill side Terrace / Stone Bund with 40% Slope Reduction	SLSUBBSN (.mgt)	slope 0 - 5	91.46	54.88
			slope 5 - 10	60.98	36.58
			slope 10 - 18	24.39	14.63
			Slope > 18%	9.14	10
		USLE_P		0.75	

Table 11: Scenario Description and SWAT parameters used to represent BMPs. Assigned by SWAT Model.

Simulation was performed for each scenario after altering the respective appropriate parameter values for the HRU`s with corresponding conservation measures and management practices.

In scenario 0, the basin existing conditions is considered. The baseline scenario corresponds to the current land management practices without conservation measures or without use of best management practices

Scenario 1, Filter strips: Filter strips are also known as vegetative filter strips or buffer strips. Filter strips were placed on all agricultural HRUs that are the combination of dry land cropland, all soil types and slope classes. In this study, filter strips (buffer) with 5m width were placed on all HRUs (hydrologic response units) of selected critical sub watersheds. The effect of the filter strip is to filter the runoff and trap the sediment in a given plot [13]. Appropriate model parameter for representation of the effect of filter strips is width of filter strip. This value was modified by editing the HRU (.hru) input table. The filter width value was assigned based on local research experience in the Ethiopian highlands [16].

In all the selected critical sub basins the dominant land cover is crop land (AGRC), so 5m width of filer strip was assigned in all HRU of the selected sub basins (1,5,11,20,23,24,30,32 and 33) (Table 12).

Selected Critical sub basins	Mean Annual Sed Loading(t/ha/yr) (1988-2008)		Percent reduction sediment yield
	Base Case (No filter strip)	**Filter strip ((5m wide)**	
1	10.507	7.31	30.44%
5	10.844	6.5	40.06%
11	12.938	4.09	68.36%

20	19.891	6.63	66.65%
23	13.438	4.2	68.78%
24	25.568	2.18	91.40%
30	14.34	1.1	92.35%
32	11.76	3.8	67.71%
33	16.063	1.18	92.67%
Total Annual Sediment Loading from the overall watershed			3.908 ton/ha/year

Table 12: Average annual change in sediment yield due to implementation of vegetation (filter strips) of 5 m widths in selected critical Sub Watersheds of the Guder basin.

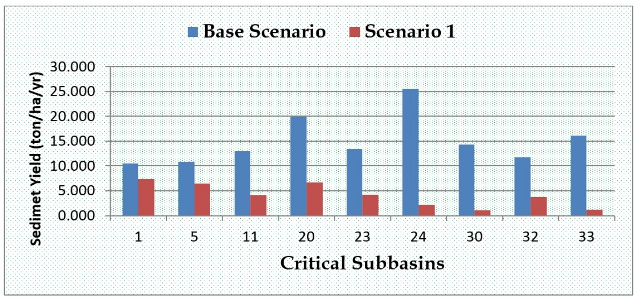

Figure 10: Mean annual change in sediment yield due to introduction of 5 m filter strip.

As the result shows (Table 13) the average annual sediment yields were reduced by 30.4% to 92.6% with implementation of vegetation strips (for 5m buffer strip). By these practices the average sediment yield is reduced by 48% from baseline condition which yields average sediment loading of to 3.908 t/ha/yr.

Scenario 2, Parallel Terraces with different Slope Length and Stone Bund, in the study area there exists of physical conservation structure like terracing, and stone bund measurement is practiced but most of the existing terrace and stone bunds are not effective (during the period 1988 to 2008). So, parallel terraces and stone bunds were placed on agricultural HRUs that are the combination of dry land cropland, all soil types and slope classes.

Around 65% of Guder catchment is agricultural land (moderate and cultivated) to which practice of terracing and stone bund would be very critical. This practice reduces overland flow, soil erosion by reducing the slope length [13]. In this scenario it is intended to evaluate the impact of reduction of slope length by 40% on the reduction of sediment yield. Also, appropriate parameters for representing the effect of parallel terrace and stone bunds are the Curve Number (CN2), average slope length (SLSUBBSN) and the USLE support practice factor (USLE_P). Though SLSSUBSN value by editing the HRU (.hru) input table, whereas USLE_P and CN2 values were modified by editing Management (.mgt) input Table.

The SWAT model assigns the SLSUBBSN parameter value based on the slope classes. In this application, the SWAT assigned values were 91.46 m, 60.98m, 24.39 m and 9.14 m for slope classes 0-5%, 5-10%, 10-18% and over 18%, respectively.

Thus, for the reduction of slope length by 40% the SWAT assigned value were changed to 54.88 m, 36.58 m, 14.63m, and 9.1m for the above slope classes. After all the parameter value for the scenario in addition to Curve Number (CN2) and USLE support practice factor (USLE_P) were change and simulated for the period the result shows that annual sediment yield reduction of 52.773% from the baseline condition. As denoted in Table 13 the reduction of Slope length by 40% for the selected critical sub basin shows that annual sediment yield of 14% to 94.5% reduction can be achieved, this is because of the increasing infiltration as a result of reducing slope length. This scenario can potentially reduce sediment to 3.504 t/ha/yr, which is 53% reduction and is much lower than the maximum tolerable soil loss rate 18 t/ha/yr (Figure 11).

Selected Critical sub basins	**Mean Annual Sed Loading(t/ha/yr) (1988-2008)**		**Percent Reduction Sediment yield**
	Base Case	**40% reduction in slope length and USLEP @0.75**	
1	10.507	5.32	49.40%
5	10.844	9.26	14.58%
11	12.938	2.7	79.15%
20	19.891	4.37	78.05%

23	13.438	3.54	73.60%
24	25.568	1.72	93.20%
30	14.34	0.83	94.22%
32	11.76	2.5	78.78%
33	16.063	0.88	94.49%
Total Annual Sediment Loading from the overall watershed			3.542 ton/ha/year

Table 13: Average annual change in sediment yield due to conservation structure by reducing slope length to 40% in selected critical Sub Watersheds of the Guder Watershed.

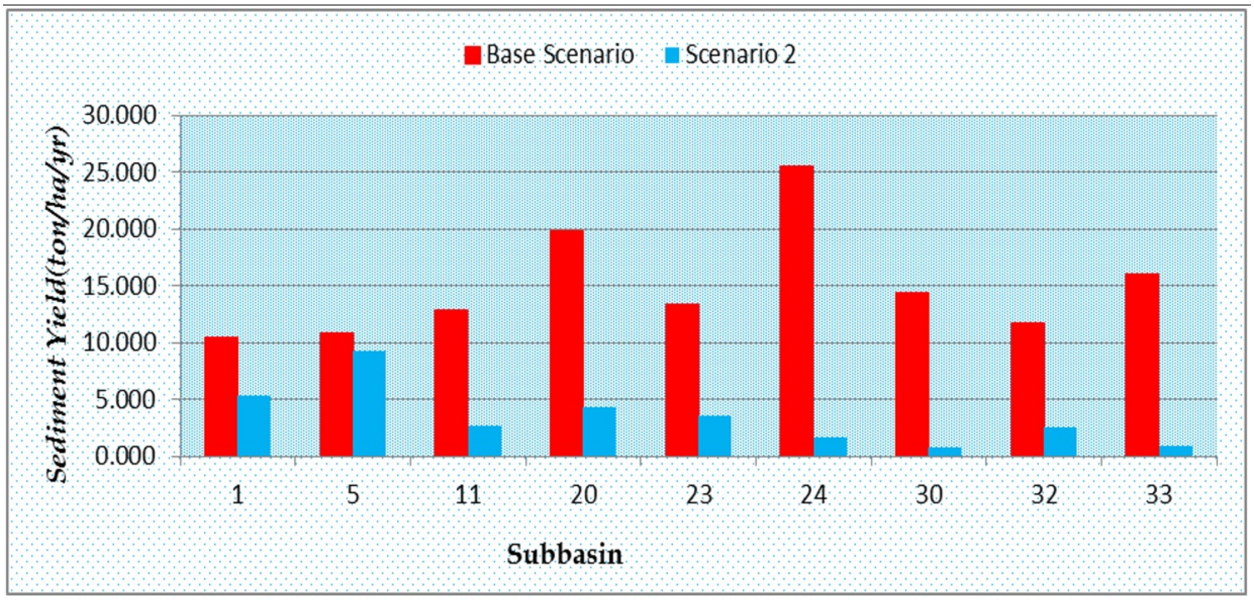

Figure 11: Mean annual change in sediment yield due to reducing slope length of conservation structure (parallel terrace/soil bund).

Comparison of BMPs scenarios

The SWAT model prediction for the Guder sub basin was 7.5 t/ha/yr, this result is quite comparable with a study conducted by Fetene [8] where Guder subasins was found the highest subasins that yields high sediment yield loading from the sub catchments of Abbay Basin. However, running the model with different catchment management scenarios provide quit good results.

The impact of BMPs at the selected critical sub basin level showed spatial variability on sediment reduction from baseline conditions as is shown below in Table 14. The sediment reductions for selected critical sub basin ranged from 30.4% to 90.6% under filter strips scenario, 14.6% to 94.5% under conservation structure (parallel terrace and stone bunds) scenario. That is the mean annual sediment was reduced to 3.908 t/ha/yr and 3.504 t/ha/yr by using filter strip scenario and conservation structure scenario respectively (Figure 12).

	Scenario 0	Scenario 1	Scenario 2
Total Mean Annual Sediment (ton/ha/yr)	7.5	3.908	3.504
Mean Percent reduction from baseline condition	_	48%	53%

Table 14: Total Mean annual reduced sediment yield for each scenario.

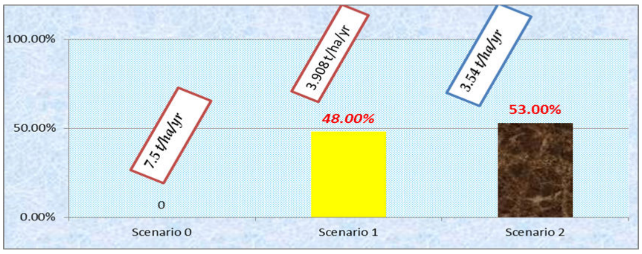

Figure 12: Comparisons of developed scenarios on the sediment yield reduction.

Thus, from the two scenario Parallel terrace and stone bund (Scenario 2) was more effective to reduce sediment than another scenario which is up to 53%. Its effectiveness became greater because the percent of cultivation area in the water shed is more to which those practices are made for. Additional scenario, afforestation was suggested for the stake holders depending up on the percentage of land available, and local topographical conditions in the basin.

Conclusions

In this study, attempts were made to model Guder watershed in terms of sediment yield, surface runoff, identification of potential sediment source areas and evaluation of alternative management interventions to reduce the onsite and offsite impact of soil erosion in the watershed.

The 17 years simulation result indicates that the simulated annual average suspended sediment yield by SWAT model was 4,842,000 ton/yr, which is 7.5 t/ha/yr. The sub watersheds that produce sever (above 18 t/ha/yr) and highest sediment (above 10 t/ha/yr) are 24 and 20 and 33, 30, 23, 11, 5 and 1 respectively.

The result shows annual soil loss rate in the study area exceeds the maximum tolerable soil loss rate 18t/ha/y at some sub basins. But the average annual sediment yield of the whole Guder watershed is around 7.5 t/ha/yr. The model prediction verified that about 9% of the watershed is erosion potential area contributing high sediment yield exceeding the tolerance limit (soil formation rate) in the study area and about 25% of the watershed area has high potential for soil erosion which produces above an 10 ton/ha/yr sediment yield of the watershed.

The 21 years simulation result indicates that the simulated annual average suspended sediment yield by SWAT model was 7.5 t/ha/yr. The sub watersheds that produce the highest sediment are 1, 5, 11, 20, 23, 24, 30, 32, and 33 exceeding the soil loss tolerable rates.

Following calibration and validation of SWAT model, also the SWAT model was applied to model spatially distributed soil erosion/sedimentation processes at monthly time step and to assess the impact of two Best Management Practices (BMPs) scenarios on sediment reductions from critical sub watersheds in the Guder watershed. For existing conditions scenario, a reasonable agreement was obtained between the model sediment yields predictions and measured sediment yields at the basin outlet. The simulation results showed that applying filter strips, conservation structure (parallel terrace and stone bunds) reduced the current sediment yields by 48% and 53% respectively both at the sub basins and the basin outlets. The effectiveness of each BMP, however, depends upon the percentage of land available, and local topographical conditions in the basin. These results indicate that applying BMPs could be effective in reducing sediment transport for sustainable water resources management in the basin.

Generally, the SWAT model performed well in predicting both the flow and sediment yields from the study watershed and the results were acceptable. It is a capable for further analysis of the hydrological responses in Guder watershed. The study can be further extended to similar watersheds in the country, particularly in the Blue Nile Basin of Ethiopia, where quantifying the total volume of runoff and sediment yields is urgently required for better land and water resources planning and management purposes.

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