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Assessing the Effect of Soil and Water Conservation Practices on Runoff and Sediment Yield on Hunde Lafto watershed of Upper Wabi Shebelle Basin

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Abstract:
A study was carried out at Hunde Lafto watershed to assess effect of Soil and Water Conservation practices on runoff and sediment yield. Soil and Water Assessment Tool (SWAT) model was used to assess the effectiveness of different Soil and Water Conservation (SWC) practices implemented in the watershed based on different scenarios (base line, stone bunds and crop residue management scenarios). The simulated sediment yield shows that soil loss rate range from 0-76.9 t/ha/yr with annual weighted average rate of 45.4 t/ha/yr. Parallel terrace (stone bunds) scenario reduced the total sediment yield from 10,978.7 t/yr to 3,734.26 t/yr relative to base simulation, which is equivalent to 65.9% decrease and reduces the surface runoff by 27% from 410.4 mm to 299.5 mm, increase base flow by 23% and lateral flow by 22.6% at outlet of watershed. While simulation of crop residue management scenario reduced total sediment yield to 4,299.84 t/yr from base simulation, which is equivalent to 60.8% reduction and the surface runoff by 23.5% from 410.4 mm to 313.6 mm, increase base flow by 18.6% and lateral flow by 19.9% at outlet. the benefits of crop residue management practices were more important in the watershed and recommended for farmers.
Keywords: Soil and water conservation, Calibration and validation, simulation, Hunde Lafto catchment, Baseline scenario, runoff, sediment yield, watershed management

1. Introduction

Soil and water resources provide the foundation for agricultural and natural resource development throughout the world. In many developing countries, expanding populations exert increasing pressure on land and water resources. For example 85% of the Ethiopian population is directly supported by the agricultural economy. However, such dependence leads to problems related to land degradation due to expansion of agricultural land (Bekele, 2003). Soil erosion is recognized as a serious problem in Ethiopia since 1973, caused land degradation. Measured soil erosion rates from slopes are even reaches extreme cases almost 300 t/ha/yr which means 1.5 cm soil depth per year in Ethiopia. Bekele, (2003) and Hurni, (1986) estimated average rate of soil erosion about 42t/ha/yr on crop land from experimental plots. Hurni *et al*., (2010) measured soil erosion rates on test plots and estimated a loss of 130-170t/ha/yr on crop land. Land degradation due to soil erosion seriously causes nutrient depletion. Land degradation as a major threat to environmental and socioeconomic of the country, the government of Ethiopia has made several interventions. Watershed management has been identified as of critical importance.

Community based participatory watershed management was from intervention started in the country. Several land rehabilitation activities like area closures, Soil and water conservation and forestation have been implemented in Ethiopia through governmental and non-governmental organizations (Dar, 2008). The largest soil and water conservation (SWC) activities in the country were those implemented during the 1970s and 1980s, mainly through food-for-work program (Woldeamlak, 2006). Evaluation of impact of implemented community based participatory watershed management is necessary. Soil bund and stone bunds were implemented in Hunde Lafto watershed in 1980s. However, with the exception of simple evaluation, effects due to Soil and water conservation intervention have not been studied. Soil loss from a watershed can be estimated based on climatic conditions, landforms and soil factors.

One method of formulating management options is to use models. To know the impact of expanded community based watershed management using computerized based hydrologic simulation model is important. Physical based watershed models that are capable of capturing these processes in a dynamic manner can be used to provide an enhanced understanding of the relationship between hydrologic processes, erosion/sedimentation, and management options. There are many models that can continuously simulate stream flow, erosion/sedimentation, or nutrient loss from a watershed such as SWAT, CREAMS (Chemicals, Runoff, and Erosion from Agricultural Management Systems), EPIC (Erosion Productivity Impact Calculator), AGNPS (Agricultural Non-Point Source model) etc.

For this specific project the SWAT model was selected. It's physically distributed and continuous time developed to predict the impact of land mgt practices on from a watershed. As data from field experiments cannot be extrapolated to a basin scale, the use of mathematical models for evaluating soil and water conservation measures is quite common, although it has been widely stated that the major limitation of modeling applications and development for arid-zone hydrology and water resources management is the lack of high-quality observations.

Therefore, the main objective of this study is to hydrologically simulate the Hunde Lafto watershed in order to assess the effect of different soil and water conservation measures on runoff, sediment yield and with specific objective of (i) To evaluate the effectiveness of different soil and water conservation measures which are implemented in the Watershed on runoff and sediment yield.

2. MATERIALS AND METHOD

2.1. Description of Study Area

Hunde Lafto watershed is located at the upper Wabi-Shebelle basin (Chercher Mountains) about 350 km East of the capital city of Ethiopia, Addis-Ababa, and 20 km North of the zonal (District) Town of Chiro, along the main road to Harar and Dire-Dawa on longitude and latitude of 40°59' to 41°00'00" E and 9°06'30" to 9°07'30"N, respectively. Mean elevation of the watershed is approximately 2089 m with maximum of 2321 m and minimum of 1857 m above sea level.

The Hunde Lafto research station was established in 1982 as the third research site in Western Hararghe, Eastern Ethiopia in collaboration with Ministry of Agriculture of Ethiopia and Centre for Development and Environment, Switzerland University, Berne. The research station covers a hydrological catchment of 241.7 ha. Soil conservation was introduced in the catchment in the form of level soil and stone bunds through the Food-for-Work campaign, which was conducted by the Ministry of Agriculture from January to May 1984 and 1985, when drought had already begun to affect the country. Since then, terraces have been adapted, gradually increased, and stabilized over the years (Hurni, 2000).

Based on Thornthwaite climate classification the Hunde Lafto watershed is generally classified as "*Dry* to *moist Weyna Dega*". The annual rainfall distribution record indicates that the area receives a bimodal rainfall type with the mean annual precipitation and annual temperature of 1229 mm and 18.3°C, respectively. According to Hurni,(2000), the study area experiences a rainfall distribution of a light secondary rainy season from March–May and a heavy primary rainy season from July–September. The area has an altitude range of 1965 to 2321 meters above sea level. The area's total length of crop growing period is about 135 days.

The farming system of the area is rain fed agriculture, which is characterized by small scale subsistence mixed farming with livestock production. The major crop cultivation in the watershed is dominated by maize and sorghum. Sorghum-maize-haricot beans (S-M-H) intercropping, typical in the Eastern Ethiopian highlands, dominates the cropping system(Schlafli, 1985). According to FAO (2000) classification system, there are two major soil groups of the Cambisol and Luvisol with area coverage of 70 and 30% respectively.

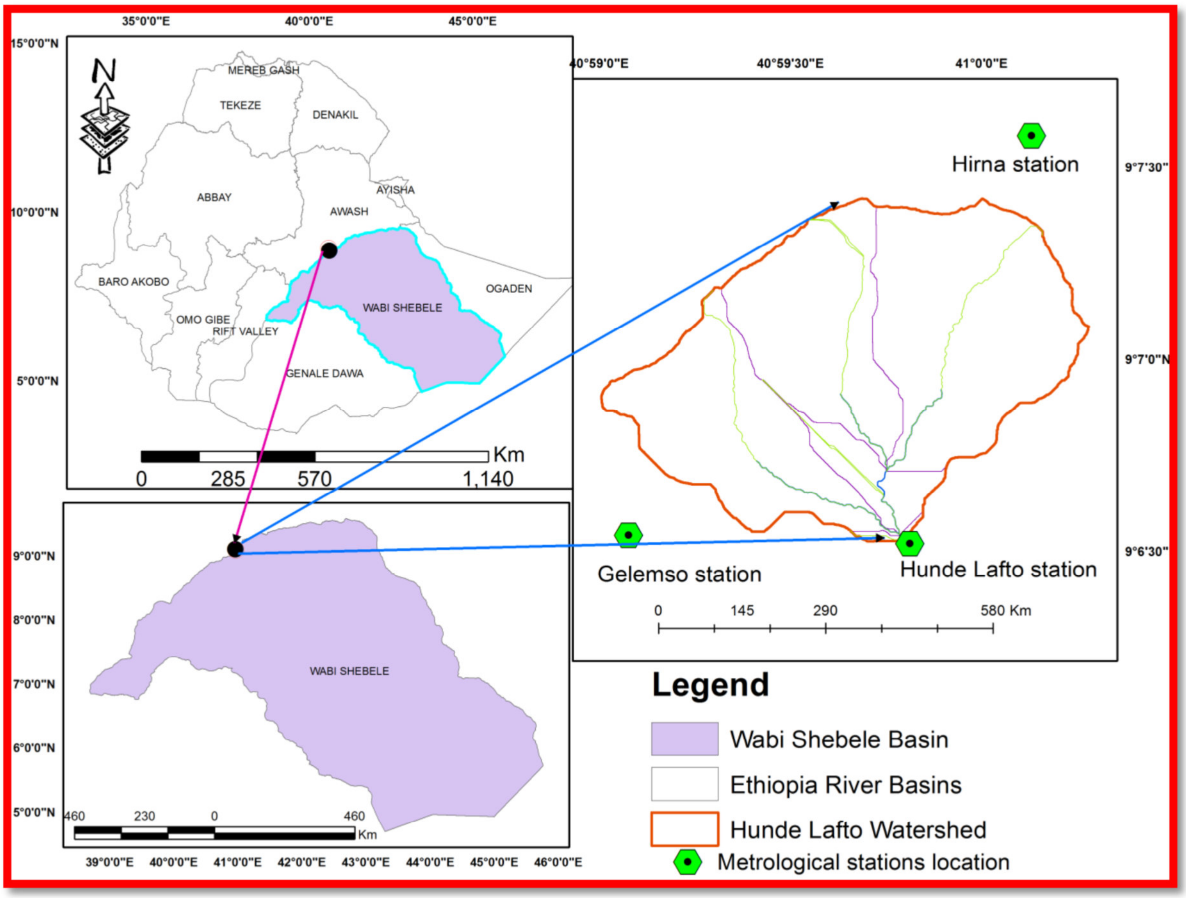
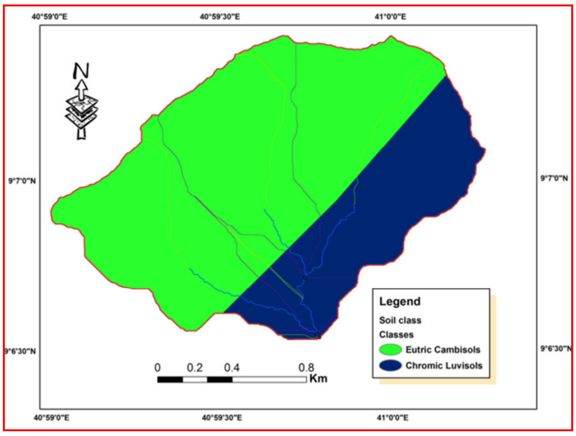


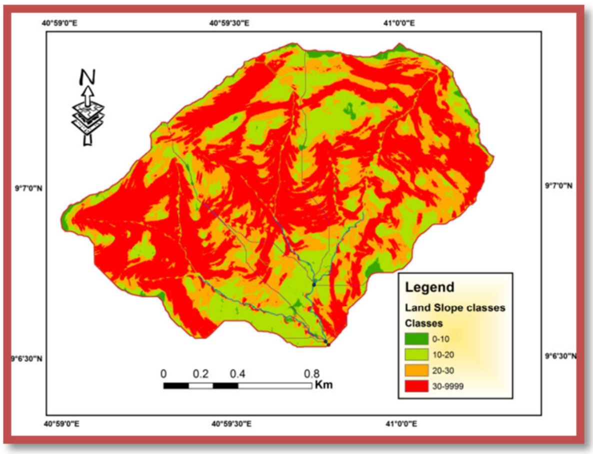
Figure 1. Map of study area

2.2. Data Collection and Analysis

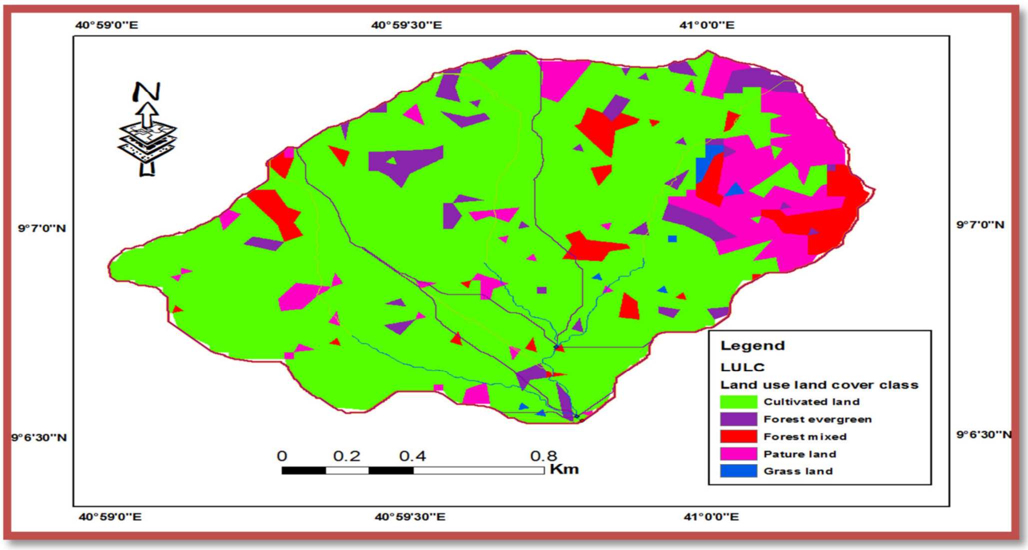
The meteorological and hydrological data required for this study were collected from the Ethiopian National Meteorological Agency (NMA), Water Land Resource Center (WLRC) and Ministry of Water, Irrigation and Electricity (MoWIE). Metrological data from 1985 - 2014 were collected and used as input in the SWAT model, Digital Elevation Model (DEM) of 1X1m resolution was used from the Center for Development and Environment (CDE), Institute of Geography, University of Berne, Switzerland. Soil Map was obtained from Ministry of Water, Irrigation and Electricity (MoWIE), Land Use Map of good resolution (30 × 30 m) was processed from remotely sensed image retrieved from USGS LandSat ETM/TM satellites (http://www.earthexplorer.usgs.gov/) of Path 167 and Row 054. The collected data were analyzed by different statistical analysis presented by means of tables, graphs, percentages etc.



a) Soil type of study area



b) Slope class of study area



c) Land use land cover map of study area

2.3. Watershed Delineation

In this study Arc SWAT integrated with Arc GIS was used to delineate the catchment area. The first step in SWAT model setup is defining watershed boundaries and loading the properly projected DEM. The watershed is delineated by using a 1m field scale resolution Digital Elevation Model (DEM) and stream networks of the study area are digitized. Based on DEM, the watershed was divided into a number of sub-basins. The sub-basins were again further subdivided into various HRU, which represent the same combination of land use, soil, and slope within a sub-basin. Then the whole watershed slopes were categorized into different slope classes. The distributions of HRUs were defined based on multiple HRU definition options.

For this particular study the threshold area was taken to be 40ha, suggested by Arc SWAT and 10% land use, 20% soil and 20% of slopes were used for creating HRU definition. With this information the model automatically delineated a watershed divided into 5 sub basins and 24 HRUs were produced. The land use land cover and soil map were prepared as shape file and classified into five classes of land use while soils were classified into two respectively in the SWAT. The prepared land use overlapped by 99.09% and soil map have an overlap of 100% were decoded using a lookup table (a table created by the user in .txt format according to SWAT input file format) so that the parameters corresponding to each soil type could be accessed from the ArcSWAT database.

2.4. Model Calibration and Validation

Prior to calibration, model parameters sensitivity analysis was performed using the global sensitivity analysis technique as implemented in SWAT- Calibration and Uncertainty Program (SWAT-CUP). Then, based on the sensitive parameters, the SWAT model was calibrated using automatic Sequential Uncertainty Fitting ver. 2 (SUFI2) procedure of SWAT-CUP (Abbaspour *et al.,* 2007). The input was observed daily flow. The lower and upper bound of the parameter values defined based on literature values (Abbaspour *et al*., 2007). The model was calibrated and validated using flow measured at Hunde Lafto gauging station between the periods of 1981 to 1985. Model calibration is the modification of parameter values and comparison of simulated output of interest to measured data until a defined objective function is achieved.

2.5. Model Performance Evaluation

For this study, the performance of the model was evaluated by using graphical visualization and statistical parameters, such as the Nash-Sutcliffe Efficiency (NSE), Percent bias (PBIAS) and coefficient of determination (R^2) (Phomcha *et al*., 2012).

2.6. Simulation of Soil and Water Conservation Scenarios

Although hydrological data that span pre- and post-soil and water management program interventions are sparse in Ethiopia, many studies have evaluated investments on stream flow patterns (Schmidt and Zemadim, 2014). Farmers in Hunde Lafto watershed used a variety of soil conservation practices, including soil bund and stone bund developed to terraces were established through the Food-for-Work campaign in 1985, when drought had already begun to affect Ethiopia. These conservation practices are about 31 years old and developed to terraces.

To study the effectiveness of soil and water conservation in the watershed, the soil and Water Assessment Tool (SWAT) model was applied to simulate the impact of these measures on sediment yield and runoff. These conservation measures were represented in the SWAT model by modifying SWAT parameters to reflect the effect of the practice has on the processes simulated within SWAT (Bracmort *et al*., 2006).

2.6.1. Baseline simulation

Existing conditions of the basin was considered as base line. SWAT model was run for existing condition (i.e before conservation structures were established from 1980 to 1985).

2.6.2. Crop residue management(Scenario I)

To simulate crop residue SCS curve number (*CN*), Manning's roughness coefficient for overland flow (*OVN)*, and USLE cover factor (*USLE_C*) were modified for the representation of residue management practices with SWAT in the watershed. In fields with residue management practices, curve number value was reduced by 2 units from its calibrated value. Crop residue on the study watershed was considered assuming 0.5 -1.0 t/ha residue is left on agricultural fields and others (Arabil *et al*., 2008). According to Bobe (2004), the USLE_P for mulched land was about 0.6 varying from 0.5-1.0 depending on different practices. While for representation of Manning's roughness coefficient for overland flow (*OVN)* in SWAT was followed as according to (Neitsch *et al*., 2005) given in Table 1.

Table 1. Values of Manning's roughness coefficient for overland flow

Characteristics of land surface	*OV N*
No till, no residue	0.14
No till, 0.5–1 t /ha residue	0.20
No till, 2–9 t/ha residue	0.30

Source: Neitsch *et al*. (2005)

USLE_C of value of the study area used depend crop cover based on Table 2 (Bobe, 2004) and Morgan (2005) used.

Table 2. USLE_C value for the watershed in different season

Month	Rainfall (mm)	Crop /Vegitation	LU	% cover/land use	C of crop/veg	Weighted C value
Jan-March	106.40	Weed	0.8	10	0.80	0.082
	106.40	Grass/plantation forest	0.2	20	0.03	0.001 0.083
Apr-Jun	289.71	Sorghum/maize	0.8	40	0.59	0.164
	289.71	Grass/plantation forest	0.2	50	0.02	0.001 0.165
July-Sept	364.55	Sorghum/maize	0.8	60	0.39	0.136
	364.55	Grass/plantation forest	0.2	70	0.01	0.001 0.137
Oct-Dec	72.81	Sorghum/weeds	0.8	30	0.69	0.048
	72.81	Grass/plantation forest	0.2	50	0.02	0.000 0.049
Total						**0.430**

Source: Bobe (2004); Morgan (2005) **CW =∑ (LU * RF fraction* C of crop/Veg)/**A_t

2.6.3. Parallel terrace (Scenario II)

Soil and stone bund over a long term stabilized and developed to terrace. These parallel terraces on the field reduce surface runoff by impounding water in small depressions and reduction of peak runoff rate. To simulate parallel terraces in SWAT, terraces were placed in watershed HRUs that are the combination of crop land, all soil types and slope classes in Hunde Lafto watershed appropriate parameters for representing the effect of stone bunds/soil bunds are the Curve Number (CN2), average slope length (SLSUBBSN) and the USLE support practice factor (USLE P).For this study, the SWAT assigned SLSUBBSN values were 18.4, 15.24 and 9.14 m for slope classes 0–10, 10-20 and over 20%, respectively. The modified parameters values for SLSUBBSN is equal to 10m for 0–10 and 10–20% slope classes, 9.1 m for over 20%, USLE P value of Table 3 used depend on slope and following Arabil *et al*. (2007), curve number decreased six units from its calibrated value to represent the reduction of surface runoff due to increased abstraction from small depressions created by terraces. The terrace type implemented in the watershed was graded terrace since the watershed slope was greater than 5%.

Table 3. USLE-P values for terracing

Slope	USLE_P terracing	
	Graded	Level
1-2	0.12	0.05
3-5	0.10	0.05
6-8	0.10	0.05
9-12	0.12	0.05
13-16	0.14	0.05
17-20	0.16	0.06
21-25	0.18	0.06

Source: Weischmeier and Smith(1978)

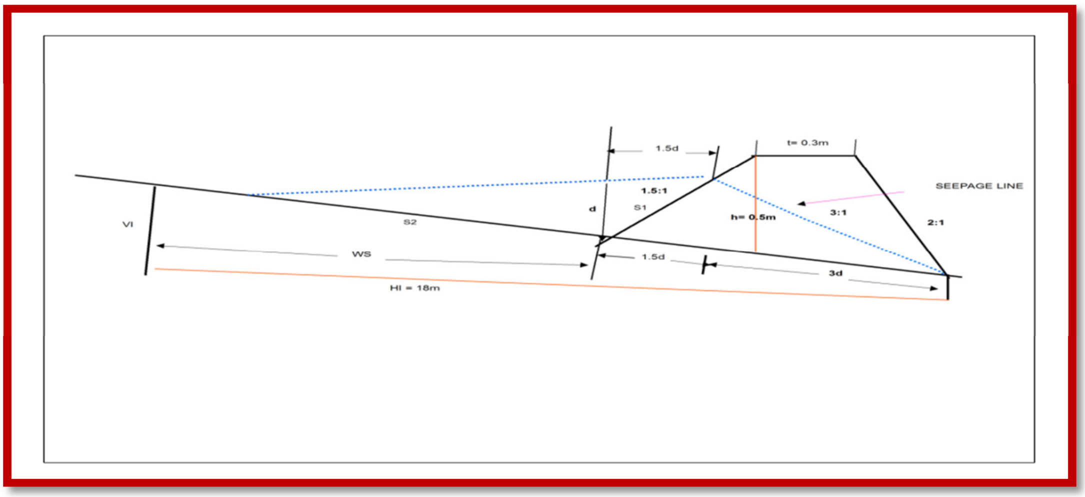


Figure 2. Side view graded bunds developed to terraces and its specification

Table 4. Summary of SWAT parameters used to represent conservation scenarios

Scenarios	Description	Parameters modified		SWAT parameters used	
				Calibrated value	Modified value
	Baseline	*		*	*
Scenario I	Crop residue	CN		77.48	75.48
		USLE_P		*	0.60
		USLE_C		*	0.43
		OVN		0.14	0.20
Scenario II	Terrace	CN		77.48	70.48
		SLSUBBSN	0-10%	18.40 m	10.00m
			10-20%	15.24m	10.00m
			>20%	9.14m	9.14m

3. RESULTS AND DISCUSSION

3.1. Sensitivity Analysis

Sensitivity analysis was carried out before calibrating the model to save time during calibration. Identifying sensitive parameters enables us to focus only on those parameters which affect most the model output. According to the result from the global sensitivity analysis, the curve number (CN2) was found to be the most sensitive parameter followed by Saturated hydraulic conductivity soil layers (R_SOL_K (..).sol), soil available water (SOL_AWC), effective hydraulic conductivity in main canal (V_CH_K2.rte), Manning's "n" value for the main channel (V_CH_N2.rte), Ground water delay time (V_GW_DELAY.gw), Threshold depth of water in the shallow aquifer (V_GWQMN.gw), and groundwater revap coefficient (V_GW_REVAP.gw) were found to be most sensitive parameters in flow simulation. Sediment yield sensitivity analysis the model wasn't done since there was no measured data of sediment yield at the outlet of the watershed.

3.2. Model Calibration and Validation

To improve the efficiency of the model during calibration the top nine ranking parameters were considered to account for the over and under prediction responses of the model. The final fitted value of the most sensitive parameters for steam flow for the watershed is given in Table 5

Calibrated parameter values for the top 9 sensitive parameters.

Table 5. Calibrated parameter values for the top 9 sensitive parameters

No	Parameters	Description	t-Stat	P-Value	Range	Fitting value	Rank
1	R_CN2.mgt	Curve number	-4.50	0.00	35-98	77.48	1
2	R_SOL_K(..).sol	Soil hydraulic conductivity	-2.10	0.03	0-2000	0.26	2
3	R_SOL_AWC(..).sol	Soil available water	-1.40	0.14	0-1	0.15	3
4	V_CH_K2.rte	Eff. Hydraulic conductivity	-1.30	0.19	0.01-500	17.2	4
5	V_CH_N2.rte	Manning's "n" value for the main channel	-1.10	0.23	0.01-0.3	0.036	5
6	V_GW_DELAY.gw	G. water delay time	-0.98	0.25	0-500	345.7	6
7	V_GWQMN.gw	Treshold depth of GW	-0.57	0.29	0-5000	1.50	7
8	V_GW_REVAP.gw	groundwater revap coefficient	-0.37	0.31	0.02-0.2	0.10	8
9	R_CANMX.hru	Maximum canopy storage.	-0.36	0.33	0-100	68.4	9

The result of simulated daily flow matched the observed values for calibration period with NSE, R^2 and PBIAS equal to 0.71, 0.96, and 25% and NSE, R^2 and PBIAS equal to 0.76, 0.95 and 20% during validation justify that the model is very good in simulating runoff. Statistical model efficiency criteria fulfilled the requirement of $R^2 > 0.5$ and NSE > 0.65 which is recommended by (Moraisi *et al.*, 2001).

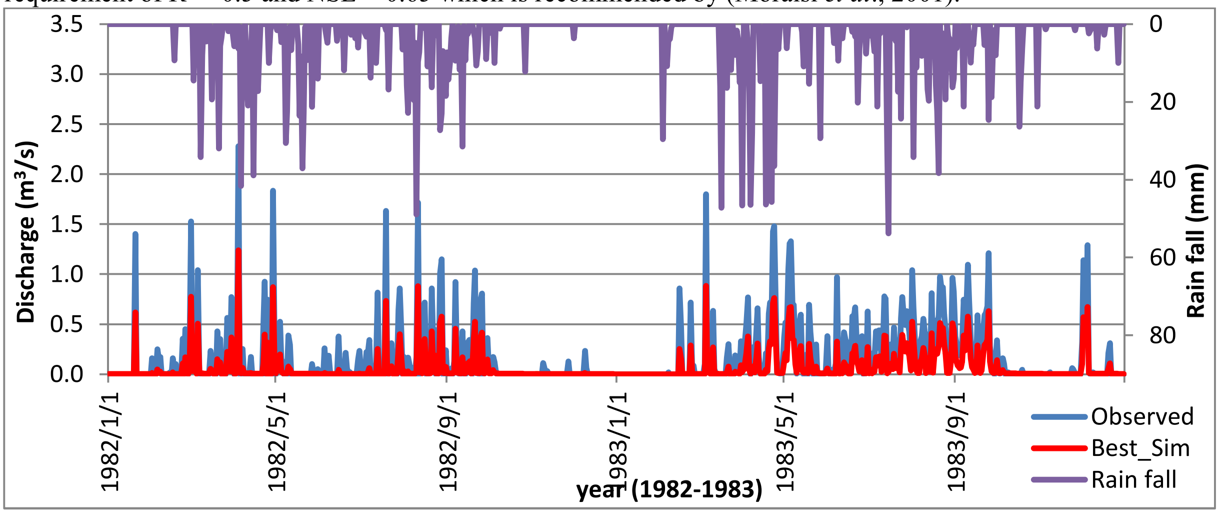


Figure 3. Observed and simulated daily flow hydrograph for calibration period

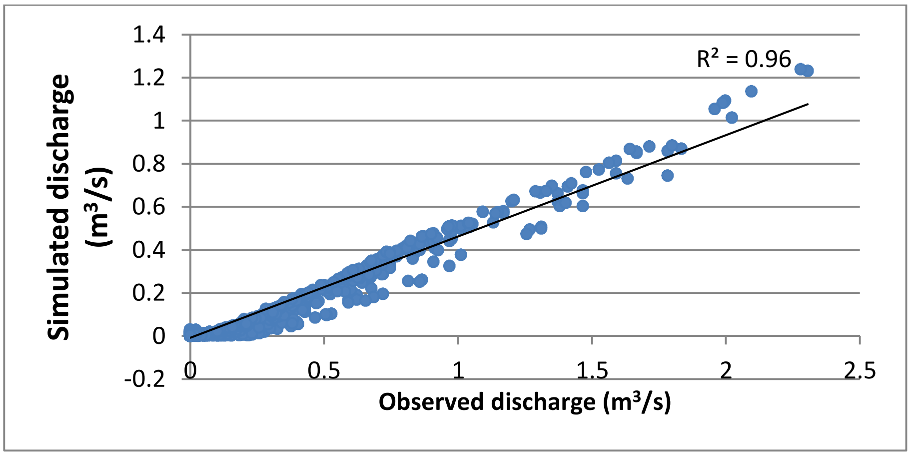


Figure 4. Scattered and best fit line for observed and simulated daily stream flow for calibration period

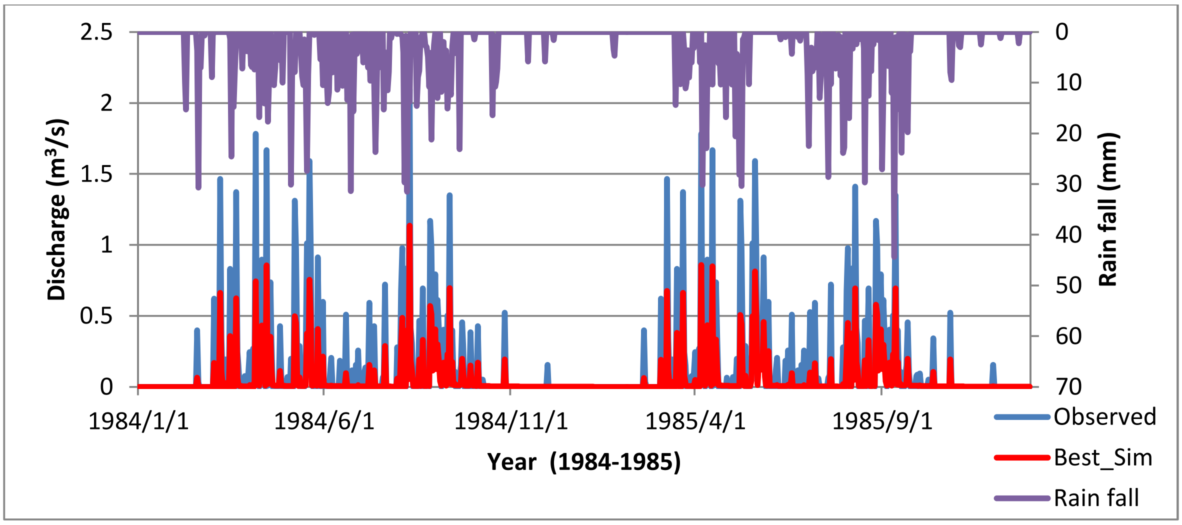


Figure 5. Observed and simulated daily flow hydrograph for validation period

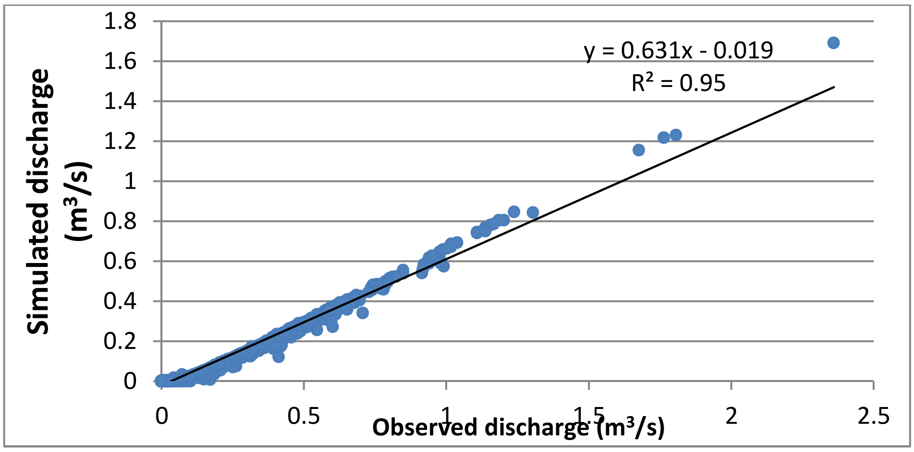


Figure 6. Scattered and best fit line for observed and simulated daily stream flow for validation period

3.3. Water Balance of the Watershed

Based on simulation period before soil and water conservation measures implemented in the watershed from 1980 to 1985.

Table 6. Average annual basin water balance before soil and water conservation intervention

No	Water balance items	Average annual (mm)
1	Precipitation	1501.5
2	Surface runoff	410.4
3	Lateral Flow	84.1
4	Base flow	265.1
5	Total water yield	728.8
6	Percolation	264.8
7	Evapotranspiration	737.5
8	Recharge to deep aquifer	13.3

The calibrated model estimates 410.4mm of average annual surface runoff, whereas recharge to the deep aquifer is approximately 13.3 mm and 737.5 mm (about 49%) of rainwater balance is lost by evapo transpiration from average annual precipitation of 1501.5 mm (Table 6). Simulation of runoff and sediment yield at sub watershed explained as Table 7.

Table 7. Simulation of runoff and sediment yield before soil and water conservation intervention

Sub-basin	Area		Simulated runoff (mm)	Simulated Sediment yield
	(ha)	(%)		(t/ha)
1	62.3	25.7	401.2	38.59
2	96.2	39.7	411	7.30
3	66.9	27.6	404	50.21
4	14.6	6	415	22.60
5	1.8	0.9	428	7.13
Total	241.8	100	99234.8 mm/yr	10,978.7 t/yr

Based on SWAT model output, spatial variability of each sub watershed the higher runoff was occurred at the South-East and central part of the watershed at SW2, SW4 and SW5 with values of 411, 415 and 428 mm respectively, whereas the lower runoff was mainly occurring at the SW1 and SW3 with values of 401.2 and 404 mm (Table 7). This shows that the runoff increases as it goes from top of watershed to the outlet of the watershed depend on watershed characteristics.

And the higher sediment yield was occurred at SW3, SW1 and SW4 with values of 50.21, 38.59, 22.6 t/ha respectively, while the lower sediment yield was mainly occurring at the SW2 and SW5 with values of 7.3 and 7.13 t/ha (Table 7). This implies that the higher sediment yield was due to the steep slope and small runoff can cause higher sediment yield. While higher runoff can cause low sediment yield depend on watershed characteristics. The estimated sediment yield rate from watershed based on sub basin and HRU ranges from 0-54.2 t/ha/year and 0-76.9 t/ha respectively whereas the annual weighted average soil loss rate from the watershed was estimated 45.42t/ha/yr. According to FAO degree of erosion classification, the soil erosion level in the watershed categorized as none to slight (0-11 t/ha/year), slight (11-20 t/ha/year), moderate (20-50 t/ha/year), high/severe (50-106 t/ha/year), and very severe (>106 t/ha/year). For this study, sub-watersheds, which produce more than 11 t/ha/year is identified as erosion critical areas (FAO,1998). Based on this, before implementation of soil and water conservation, about 40.6% of the watershed area was under slight, 31.7% under moderate (based on HRU area) and 27.7% under high degree of erosion (Table 7). The observed average sediment yield at the outlet of the Hunde Lafto from plot and converted for the watershed was 16,736.1 t/yr. The SWAT model predicted 10,978.7 t/yr for existing conditions (Table 7). This result is comparable with the predicted (simulated) using SWAT model in the watershed for existing condition. To assess effect of conservation practices in the watershed, the SWAT model calibrated and validated for stream flow with adjusted parameters were used to simulate different conservation practice scenarios on runoff and sediment yield and running the model with different catchment management scenarios provided very interesting results. The soil and water conservation scenarios simulated in the SWAT were as below.

3.4. Parallel terrace (Stone bund)

After base line simulation (existing condition) was run using SWAT model, sensitivity analysis, the calibration and validation takes place. Then, at the point objective function(R^2 and NSE >0.5) satisfying the calibration, the final parameters calibrated value were edited in edit SWAT input and parameters desired to be modified were changed and SWAT model was run again to simulate effect of parallel terrace. The simulation of parallel terrace (stone bunds) scenario reduced the total sediment yield of 10,978.7 t/yr to 3,734.26 t/yr, which is equivalent to 65.9% and reduces the surface runoff by 27% from 410.4 mm to 299.5 mm from baseline simulation (Table 9) using weather data of 1986-2014. This result is quite comparable with Betrie *et al*. (2011) who found that terraces would reduce sediment yield by about 41% at Blue Nile Basin using SWAT model. And similar studies by Santhi *et al*. (2006) found that contour terraces would reduce sediment yield by between 84 and 86% using SWAT simulations at the sub basin level. In addition, according to Mwangi (2011) simulation of bench terraces reduced sediment yield from 32,620 ton/yr to 4930 ton/yr and equivalent to 85% decrease.

Table 8. Water balance after simulation of parallel terraces in Hunde Lafto watershed

No	Water balance items	Average annual (mm)
1	Precipitation	1562.6
2	Surface runoff	299.5
3	Lateral Flow	103.1
4	Base flow	326.5
5	Total water yield	724.9
6	Total sediment yield (t/ha)	3734.2

The calibrated model estimates average annual surface runoff of 299.5mm, lateral flow of 103.1mm, base flow of 326.5mm and total water yield of about 724mm after implementation of parallel terrace (table 8).

Table 9. Comparison of water balance before SWC and Parallel terrace implemented in the watershed

Simulation	Surface runoff (mm)	Lateral flow (mm)	Base flow (mm)	Water yield (mm)	Total sediment (t/yr)
Base simulation	410.40	84.10	265.10	728.80	10978.70
Simulation of Terraces	299.50	103.10	326.52	724.93	3734.26
% change	**-27.00**	**22.60**	**23.00**	**-0.53**	**-65.90**

The water balance after the simulation of the parallel terraces reduces the surface runoff by 27% from 410.4 mm to 299.5 mm, increase base flow by 23% and lateral flow by 22.6% (Table 9). The enhanced infiltration by terraces would recharge the shallow water table reducing the surface runoff. The water stored in the shallow aquifer released to the streams as the base flow. The implication of this is that, flooding incidences would reduce as the surface runoff is reduced and there would be more regulated stream flows which would run for an extended time because the base flow takes longer time to reach the streams than does the surface runoff. Generally, due to implementation of parallel terrace surface runoff and sediment yields were reduced at sub watershed level.

3.4.1. Effect of parallel terrace on sediment yield at sub basin level

To assess effect of parallel terrace on sediment yield at sub basin level, the SWAT model was successful calibrated for stream flow at the outlet of the watershed and the sediment outflow from each sub-basin has been simulated. The impact of parallel terraces at the sub-watershed level showed a wider spatial variability on sediment reduction from baseline conditions as is shown in Figure 21. The sediment reductions ranged from 17.3% to 80.6%. From the result, the sediment yield in four sub basins were below critical erosion level according FAO erosion classification except sub basin three with sediment yield of 8.6 to 26.3 t/ha/yr. This is due to farmers remove soil and water conservation to save land for agriculture and requires terrace maintenance.

3.5. Crop residue management

After base line simulation (existing condition) was run using SWAT model, sensitivity analysis, the calibration and validation takes place. Then, at the point objective function (R^2 and NSE >0.5) satisfying the calibration, the final parameters calibrated value were edited in edit SWAT input and parameters desired to be modified were changed and SWAT model was run again to simulate effect of crop residue management.

Table 10. Simulation of runoff and sediment yield after crop residue intervention at sub-watershed level

Sub-basin	Area (ha)	Simulated runoff (mm)	Simulated Sediment yield (t/ha)
1	62.30	233.80	12.10
2	96.20	286.90	5.00
3	66.90	349.50	19.40
4	14.60	335.30	9.30
5	1.80	357.20	1.53
Total	**241.80**	**72419.10 mm/yr**	**3734.26 t/yr**

The simulation of runoff and sediment yield after crop residue intervention at sub watershed level as explained on Table 10, the runoff increases at sub watershed 3, 4 and 5. And higher sediment yields at SW1 and SW3 with values of 12.1 and 19.4 t/ha respectively were observed. This shows the above mentioned sub watersheds were highly cultivated area as well as characterized by steep slope area. When compared with before SWC implemented in the watershed, surface runoff and sediment yield were reduced at both sub watershed and watershed level as Table 10.

Table 11. Comparison of water balance for the simulation of crop residue with before SWC implemented in Hunde Lafto watershed

Simulation	Surface runoff (mm)	Lateral flow (mm)	Base flow (mm)	Water yield (mm)	Total sediment (t/yr)
Baseline simulation	410.40	84.10	265.10	698.17	10978.70
Simulation of crop residue mgt	313.64	100.84	314.52	698.08	4299.84
% change	**-23.50**	**+19.90**	**+18.60**	**-0.01**	**-60.80**

In this study the simulation of crop residue management scenario reduced the total sediment yield to 4,299.84 t/yr from baseline simulation of 10,978.7 t/yr, which is equivalent to 60.8% reduction. The water balance after the simulation of the crop residue management reduces the surface runoff by 23.5% from 410.4 mm to 313.6 mm, increase base flow by 18.6% and lateral flow by 19.9% and the base flow has increased by 18.6% from Table 11.

The implication of this phenomenon on the ground is that there would be reduced flash floods in the area and more recharge of the shallow aquifer. Therefore there would be increased base flow into the rivers even long after the rains. The increased base flow would result in more water going to the reservoir during the dry periods after the rains.

3.5.1. Effect of crop residue management on sediment yield (erosion) and runoff at sub basin level

Similar to the parallel terrace, to assess the effect crop residue on sediment yield (erosion) at sub basin level the SWAT model was successful calibrated for stream flow at the outlet of the watershed and the sediment outflow from each sub-basin has been simulated. The simulation result indicate that crop residue management reduced the soil erosion in the sub basin compared to existing condition with spatial variability of 30.5% to 79% (Table 12 and Figure 7&8). Sub-basins 1 and 3 were found to have a relatively higher sediment yield. These are soil erosion hotspots which should be prioritized and require soil conservation measures maintenance or implementation. The main factors contributing to high sediment yield in this part of the watershed is the farmers in the area didn't care for their land they remove soil and water conservation measures and area is characterized by high slope.

Table 12. Comparing average sediment yield in base line with crop residue management

Sub basin	Average Crop residue Sed (t/ha)	Average Baseline Sed (t/ha)	% reduction
1	12.20	38.60	68.40
2	5.07	7.20	30.50
3	19.30	50.20	61.50
4	9.40	22.50	58.20
5	1.50	7.15	79.00

Generally, simulation of different soil and water conservation scenario at Hunde Lafto watershed shows reduced surface runoff and sediment yield, increase deep percolation result in increment of lateral flow and ground water flow on annual, monthly and daily basis. And Parallel terrace which established in the watershed in 1985 shows great reduction in surface runoff and sediment yield compared to crop residue management and base scenario

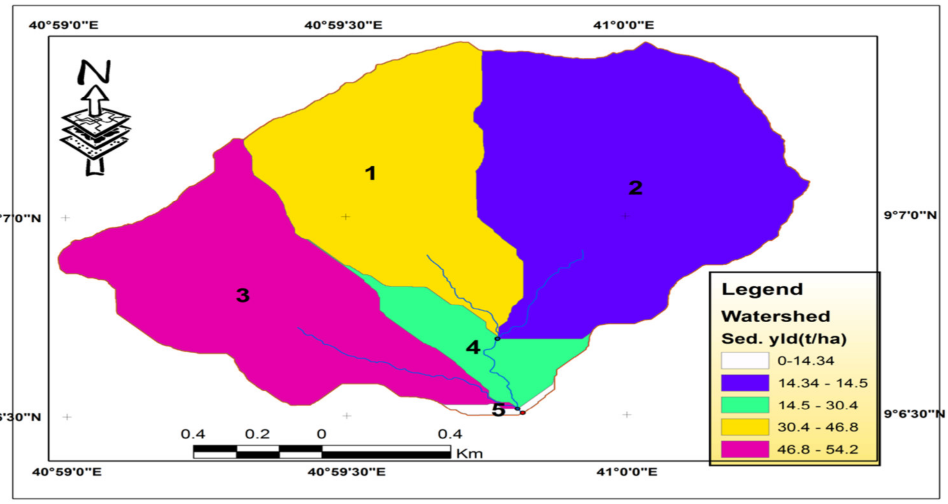


Figure 7. The spatial visualization of sub basin wide sediment yield in t/ha in Hunde Lafto catchment before SWC implemented

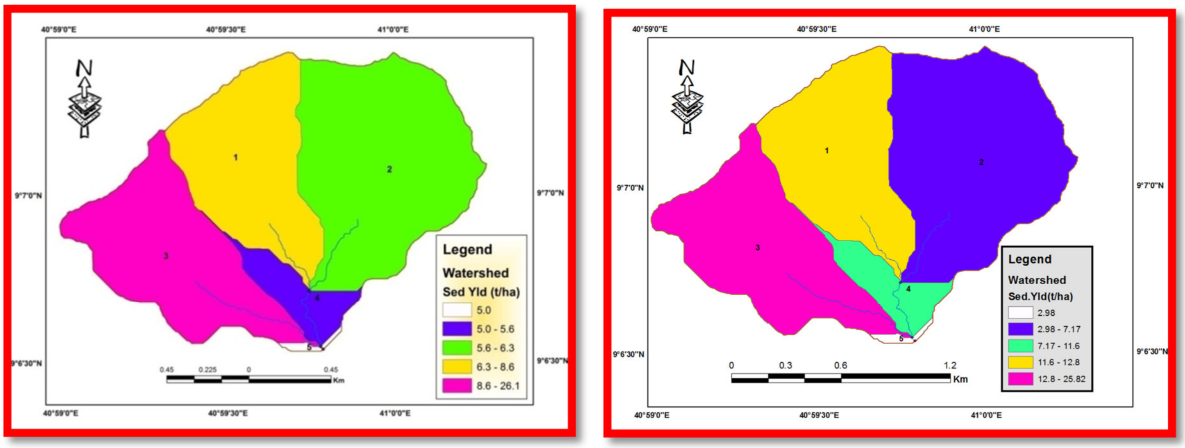


Figure 8. The spatial visualization of sub basin wide sediment yield in t/ha after parallel terrace(left) and crop residue management(right) simulation.

4. Conclusion

The calibrated SWAT model satisfactorily simulated and represented observed stream flow. The model showed average runoff and sediment yield loss from the catchment was estimated and the erosion prone area at sub basin and basin level was identified. The Hunde Lafto watershed was covered by two most common conservation practices stone/soil bunds and crop residue management. Terracing and crop residue management in SWAT were simulated by adjusting both erosion and runoff parameters based on (Arabil *et al*., 2008) and local research experiences, such as the USLE practice (USLE_P) factor, the slope length (SLSUBBSN) factor and curve number (CN). The simulation results showed that applying crop residue management and parallel terrace (stone bunds) scenarios reduced sediment yields both at the sub basins and the basin outlets. In this study, parallel terrace located in the entire part of the watershed shows greatest reduction in surface runoff and erosion, which is about 27% and 65.9%, respectively, as well as increase ground water flow by 22.6% at the basin outlet on annual basis. While crop residue management reduced surface runoff by 23.5% and total sediment yield by 60.8% compared to existing condition. Both the crop residue management and parallel terraces reduced surface runoff and increased base flow with only minimal decrease in total water yield. Parallel terraces were the most effective soil conservation practice in reducing sediment yield as well as increasing water infiltration. From the result obtained from simulation, parallel terrace reduced surface runoff and erosion better than crop residue management.

Generally to validate model simulation advanced soil and water conservation measures impact assessment may be needed to satisfyingly consider the interaction between various conservation structures and heterogenic landscape conditions to support proper decision making in the future.

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