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Estimation of Soil Loss, Evaluating Effectiveness of Soil and Water Conservation Practices and Identification of Erosion Hotspot Area, the Case of Gina-Beret Watershed, Central Highlands of Ethiopia

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Research Article

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ABSTRACT

Soil erosion is a global problem which has eroded the top soil that is vital for crop production. This study was conducted in Gina-beret watershed in 2017/2018 to estimate soil loss, evaluate effectiveness of Soil and Water Conservation Practices (SWCP) and identify the erosion hotspot areas. The impact of SWCP on soil loss was investigated using the USLE model to areas before and after implementation of SWCP. Moreover, field measurement of soil erosion was conducted using erosion pin to validate the estimated soil loss with the model. Satellite imagery of 2007 and 2017 were used for generating the land management factor of USLE. Soil laboratory analysis was done for bulk density. The modeling result shows an average soil loss rate of 26.68 t ha^{-1} yr^{-1} and 14.07 t ha^{-1} yr^{-1} in the year of 2007 and 2017. Respectively. Field measurement showed the current soil loss rate as 16.26 t ha^{-1} yr^{-1}. Erosion hotspot areas in the watershed which needs special treatment was identified and mapped at micro-watershed scale. So as to reduce the soil erosion problems, SWC measures might start from identified hotspot areas so that integrated physical and biological soil and water conservation practices shall have proposed.

Keywords: Soil erosion; USLE; GIS; Satellite imagery; Erosion pin; Gina-Beret watershed

INTRODUCTION

Globally soil degradation is affecting 1.9 billion ha and increasing at a rate of 5 to 7 million ha each year. About 80% of the world's agricultural land suffers moderate to severe erosion (Gossa) and 10% suffers slight to moderate erosion. Among all degradation processes, including soil acidification, salinization and nutrient mining, soil erosion is by far the most common source of land degradation, accounting for 84% of affected areas [1].

In Sub-Sahara Africa (SSA), soil erosion mainly occurred due to the lack of vegetation cover, deforestation and overgrazing. Soil erosion is generally more acute in tropical areas where rainfall is more intense and soils are highly erodible due to the relatively shallow depth and low structural stability. Soil erosion is a major form of land degradation resulting in both on-site and off-site effects. It generates strong environmental impacts and major economic losses in decreased agricultural production and off-site effects on infrastructure and water quality by sedimentation processes. In Ethiopia the main factors that accelerate soil erosion are rapid population growth, cultivation on steep slopes, clearing of vegetation and overgrazing. Such unsustainable and exploitative land use practices due to an increasing demand for food, fiber and fodder by the growing human and livestock populations are responsible for accelerated soil erosion in many parts of Ethiopia [2].

MATERIALS AND METHODS

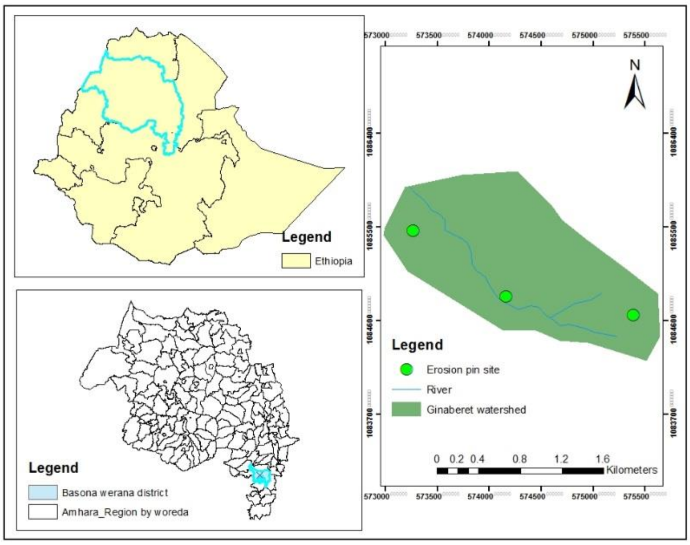
In Ethiopia, effectiveness of Soil and Water Conservation Practices (SWCP) was evaluated by their soil conserving ability. Coping these problems, soil and water conservation goal were started since the mid-1970s and 80s to alleviate problems of erosion and low crop productivity (Shimelis). As a result, the government implemented SWCP to reduce soil erosion. Since then, various mechanical (bunds, terraces, check dams, cutoff drains and waterways) and biological (homestead and communal tree plantations and enclosures) SWCP have been implemented in drought-prone areas (MOA, Amsalu and de Graaff). The implementation of sustainable land management practices may help to increase agricultural productivity, improve ecosystem functions and enhance resilience to adverse environmental impacts. SWCP undoubtedly have affected positively the productivity of agriculture where agriculture is hampered by drought, erosion, low soil fertility and moisture stress [3].

There are several causative factors that control the spatial pattern and amount of soil loss in an area. The most important of such factors are the erosivity of rainfall, erodibility of soils, vegetation cover, conservation measures and topography of the area (Mekonnen and Melesse). Understanding soil erosion processes, both in time and space, as well as their causes is a prerequisite to design and implement appropriate SWCP and approaches that eventually contribute to sustainable land management (Hurni). Therefore, soil erosion is a severe problem in Gina-Beret watershed before SWCP was done. The Gina-Beret watershed is characterized by highland areas which have high livestock pressure; high and intensive rainfall combined with poor old cultural practices. Which causes severe soil erosion and seriously damaged the productivity and sustainability of agricultural lands. Recently, the watershed was treated with SWCP having a potential to reverse the problem. However, no investigations are conducted to assess the impact of the implemented SWCP in the watershed. Therefore, this study was conducted to estimate soil loss using USLE model, to investigate the effectiveness of SWCP and to identify erosion hotspot areas for Gina-Beret watershed [4].

Description of the study area

The study was conducted in Gina-Beret watershed, Basona Werana district, North Shewa zone, Amhara regional state, Ethiopia. The watershed is located 165 kms North of Addis Ababa, the capital city of Ethiopia and lies between the coordinates of 9°48’30’’ to 9°49’29’’ N latitude and 39°39’55’’ to 39°41’22’’ E longitude with an area of 282 ha. The micro-watershed was selected based on its treatment with SWCP for a long period of time (Figure 1) [5].

Figure 1. Elevation and slope ranged 2903 m to 3162 m above sea level and 0%-72% respectively and agro ecology zone is moist-dega.



Data type and sources

Both primary and secondary data sources were used for this study. Twenty years monthly rainfall data collected from three research meteorological stations (Andit Tid station, Debre Birhan station and Inewari station) for the period 1998–2017 and soil unit map of the study watershed was found from Amhara region digital soil map developed at a scale of 1:50,000 by development studies associates and Shawel consult international. Aster digital elevation Model (20 m×20 m) downloaded from global land cover facility, which was resampled to 20 m×20 m spatial resolution was used to generate slope Length–Steepness (LS) factor; Thematic Mapper (TM) multi-spectral image with spatial resolution of 15 m was used to classify the land use/cover map of the year 2017 and Google earth was used to digitized the land use/cover of 2007, Google earth and resonances survey was used for identification of management practices of 2007 and 2017 in Gina-Beret watershed [6]. Farmer’s interview and group discussion had been done during data collection and different journals and theses also used. Other than this secondary data, published and unpublished materials such as research reports, census reports and journals obtained from different sources were used. GPS was used to collect point of experimental site, location of erosion pins, soil sample points and for delineating watershed boundary. Core sampler used to collect undisturbed soil sample from the field. 1:50,000 scale topographic map of Basona Werana district to digitize contour lines and derive DEM for slope generation [7].

Field measurement

Transect walk was done with planning team in the watershed in all direction to collect the data in the watershed like the farming practices, the soil color and soil texture, the actual land cover/use pattern and slope of the watershed, it was also used to asses effectiveness of SWCP by informal discussion with planning team and farmers and analyzing which type of conservation structures are effective [8].

Erosion pin method was applied to measure the amount of soil loss from the field during field measurement. The watershed was classified into three slope classes upper (15%-30%), middle (8%-15%) and lower (<8%). From each slope class 0.14 ha-0.5 ha of farmlands were selected. In each farmland the number of erosion pin were different. Totally 71 erosion pins were installed. Measurements of the pin heights were taken before and after the rainy season [9].

The mean soil loss was calculated by taking the difference between after rainy season and before rainy season pins height. Using core sampler undisturbed soil samples were collected from three typical slope classes where erosion pins are installed. A total of 18 soil samples were collected from 5 cm-20 cm depth of all surveyed plots to estimate the Bulk Density (BD). The BD was used to convert the volume of soil loss, which is found after multiplied depth of soil loss resulted from erosion pin analysis by plot area to mass of soil lost from the given plot area [10].

Data analysis

Modeling: To predict soil erosion at Gina-Beret watershed USLE was applied (Eq. 1) which is in the Ethiopian condition. This equation is a function of five input factors in raster data format: Rainfall erosivity, soil erodability, slope length and steepness, cover management and support practice. These factors vary over space and time and depend on other input variables. Therefore, soil erosion within each pixel was estimated with the USLE. The USLE method is expressed as:

$$A = R \times K \times LS \times C \times P \quad \text{......................Eq. 1}$$

where A is the computed spatial average of soil loss over a period selected for R, usually on yearly basis (t ha^{-1} yr^{-1}); R is the rainfall-runoff erosivity factor (MJ mm ha^{-1} h^{-1} y^{-1}); K is the soil erodability factor (t ha h ha^{-1} MJ^{-1} mm^{-1}); LS is the slope length steepness factor (dimensionless); C is the cover management factor (dimensionless, ranging between 0 and 1.5); and P is the erosion control (conservation support) practices factor (dimensionless, ranging between 0 and 1) [11].

Rainfall erosivity factor (R)

The R-factor represents the erosive force of a specific rainfall event. USLE in their original equation require rainfall intensity data. Due to the absence of rainfall intensity data. R-correlation established by Hurni for Ethiopia, which was used in other similar studies. In this study rainfall erosivity was calculated using equation 2.

$$R = -8.12 + 0.562P \quad \text{..................................... Eq. 2}$$

Where R is the rainfall erosivity factor and P is the mean annual rainfall (mm).

The mean annual rainfall for 10 years (1998-2007) and (2008-2017) was first interpolated to generate continuous rainfall data for each grid cell by Invers Distance Weighted (IDW) in Arc GIS environment [12].

Soil erodibility factor (K)

The soil erodibility (K) factor for the watershed was estimated based on soil types and soil color referred from Hurni classification. Finally, the resulting shape file was changed to raster with a cell size of 20 m × 20 m. The raster map was reclassified based on the erodibility values (Table 1).

Table 1. Soil erodiblity factor (K) values for different soil types in the Ethiopian condition.

Soil type	Soil erodiblity factor(K) value
Eutric leptosols	0.2
Eutric vertisols	0.15

Topographic factors (LS-factor)

The slope length and slope steepness factors were used to calculate soil loss as an input variable for the model by other studies such as Bewket and Teferi and Kamaludin et al. This study also calculated slope length and steepness using equation 3.

$LS=(\text{flow accumulation} \times \text{cell size}/22.1)^{m} \times (0.065+0.045S+0.0065S^{2})$ ....Eq. 3

Where cell size is 20 m, S=slope in percent/slope steepness, m exponent that depends on slope steepness.

m=0.2 if S<1%, 0.3 if S (1%-3%), 0.4 if S (3%-5%), 0.5 if S ≥ 5%

To estimate the m value 95% of the study area has slopes of above 5% gradient and steeper. Because of this, the m value of 0.5 was used to calculate the slope length. Finally, the LS factor with a spatial resolution of 20 m was generated from DEM using ArcGIS10.

Land cover/use (C-factor)

The C-factor represents the land cover and describes how different land cover classes affect soil erosion (Wischmeier and Smith). This factor is considered as the main soil erosion controlling factors. The C value of each land cover class was determined based on the value adapted to the Ethiopian condition (Table 2) with a spatial resolution of 15 m was generated from satellite image of 2017 and Google earth image of 2007 using ArcGIS10.

Table 2. Land use factor C value for each land use type in Ethiopian condition.

Land use	C-factor value
Crop land	0.37
Grazing land	0.12
Forest land	0.05
Built up area	0.01
Rocky area	0.05
Water body	0

Management practices factor (P-factor)

The P-factor refers to management practices such as terracing, mulching, strip cropping, contouring ploughing and other protection measures and its effect in reducing the amount and rate of runoff. In this study soil/stone bunds, contour ploughing and ploughing up and down methods were considered to determine the P-factor for cropland because these are the dominant supportive management factors practiced to reduce soil erosion in the study area. These management activities are highly depending on the slope of the area Atesmachew et al. The p-value of each management practices was determined based on the value adapted to the Ethiopian condition (Table 3).

Table 3. Management practices factor of each land use type in the Ethiopian condition.

Land use type	Slope (%)	P factor value
Ploughing on contour	All	0.9
Ploughing up and down	All	1
Terrace (stone/soil bund)	All	0.6

After soil loss rates for the reference years are estimated using USLE and compared with the result from the erosion pin method, the larger soil loss rate was assumed to be the watershed average soil loss value. Using the soil loss results of 2007 and 2017 as an input coupled with the response of the community, effectiveness of the applied conservation measures was examined through comparison and interpretation of the change in the soil loss rates. Besides, erosion parameters significantly influenced by the conservation measures were also identified. Finally, based on the soil loss rate maps and the pre-determined erosion hazard categories, erosion hotspot areas were identified through ArcGIS environment. Finally, proportional areas of the identified erosion hazard zones were determined for ease of solution recommendation [13].

RESULTS AND DISCUSSION

Soil erosion in Gina-Beret watershed

In this study, USLE model was integrated with GIS and RS techniques to conduct cell by cell calculation of mean annual soil loss rate (t/ha/yr). Raster map of each USLE parameters were produced from different data source. The results are presented and discussed as follows.

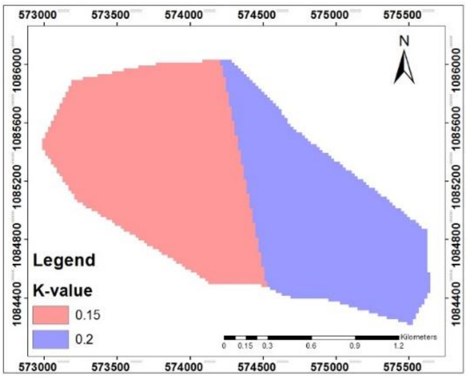
Rainfall erosivity factor (R)

The annual rainfall of the watershed was found to be ranging from 989.48 mm to 1746.1 mm with annual average of 1330 mm and 1073 mm to 1464 mm with annual average of 1222 mm, respectively for 2007 and 2017. Rainfall-runoff erosivity (R factor) of 2007 and 2017 were found to be 739.34 MJ mm ha^{-1} h^{-1} yr^{-1} and 678.64 MJ mm ha^{-1} h^{-1} yr^{-1}, respectively.

Soil erodibility factor (K)

The soil types which were found in the study area are Eutric vertisols and Eutric leptosols with the total coverage in the watershed of 53.33% and 46.67%, respectively. Their corresponding K values were also given 0.15 Mgh MJ^{-1} mm^{-1} and 0.2 Mgh MJ^{-1} mm^{-1}, respectively (Figure 2). The erodiblity value of the watershed is very low which is in line with (Pauwels). The Eutric vertisols 53.33% was found to be resistant to erosion than Eutric leptosols. This result agree with Tesfaye and Hailmarkos.

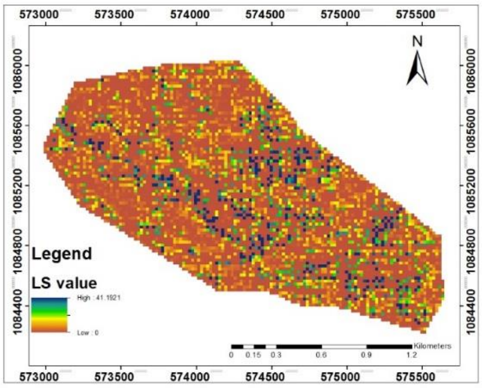
Figure 2. Map of K factor of study area.



Topography factor (LS)

In USLE, the LS factor represents a ratio of soil loss under given conditions to that at a site with the "standard" slope steepness of 9% and a slope length of 22.1 m plot (Robert and Hilborn). The steeper and longer the slope, the higher is the erosion (Mekonnen and Melesse). The slope length and slope steepness can be used in a single index, which expresses the ratio of soil loss as defined by Wischmeier and Smith. Finally, the LS factor map was generated using ArcGIS spatial analysis raster calculator function (Figure 3).

Figure 3. Map of LS factor of study area.

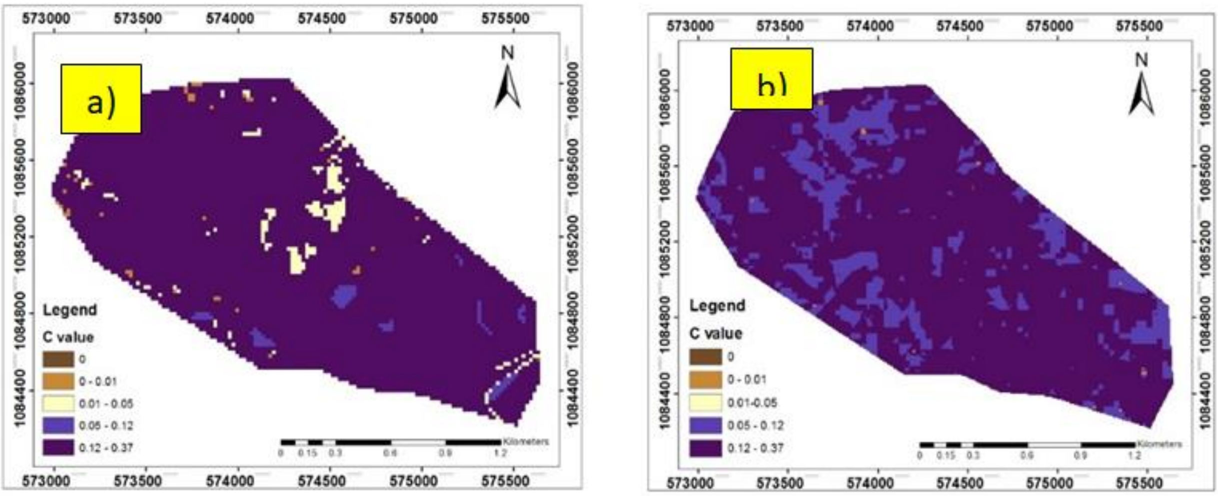


The result indicated that for the year 2007 slope steepness and slope length factors were found to contribute 0.0 to 41.79 to soil erosion. While in 2017, contribute from 0.0 to 35.25 to soil erosion the difference in the result is attributed to the reduction in the slope from 2007 to 2017. This might be because of terracing in the watershed for about 10 years. Consequently, the topographic factor was found to have significant effect on soil erosion in the watershed.

Land use factor (C)

To generate C-factors for different management practices existing in the area, data on the land cover/use type are required Foster et al., Therefore, Landsat 7 satellite image and Google earth Image were used to generate land cover/use map of 2017 and 2007 respectively (Figure 4).

Figure 4. Map of C factor of study area (a) 2007 and (b) 2017.



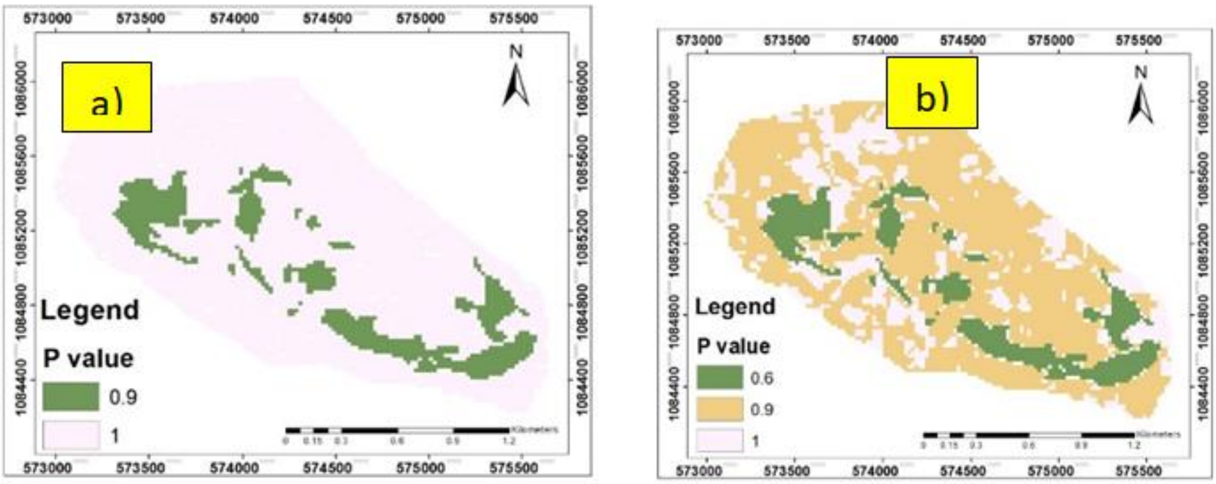
From the result (Figure 4) the land use and land cover of the watershed in 2017 has indicated that six land use classes were recognized, dominated by crop land (228.59 ha), grazing (41.15 ha), plantation (9.18 ha), built up area (0.43 ha), degraded land (2.6 ha) and water body (0.03 ha). However, the situation in the year 2007 were some-what different in that crop-land cover (266.6 ha), grazing (4.2 ha), plantation (1.52 ha), built up area (1.6 ha), degraded land area (6.8 ha) and water body (0.03 ha). The corresponding C factor values were assigned to be 0.37, 0.12, 0.05, 0.01, 0.05 and 0.00 respectively. Based on the 2017 result, the larger area (80.6%) of the crop-land contributed large amount to result in the C factor to have 0.37 value. Therefore, C factor was the dominant factor next to rainfall for soil erosion in the watershed.

Management practice (P) value

Part of the watershed that were treated for the last seven years with terracing and stabilize with Biological SWCP through the agricultural extension program of the government corresponding P values of each land cover classes was determined based on the value adapted to Ethiopian condition (Hurni). Thus, in 2017 the agricultural lands are classified into six slope categories and the suggested P values. However, because of the poor conservation practices, the P value in the year 2007 was higher than that of after conservation.

From the result (Figure 5), there is a big difference between the two years on management practices. This was due to the fact that from the total area of watershed 40% of the land was found covered by SWCP in 2017. This indicates that management practices were found to bring highly significant difference on soil loss.

Figure 5. Map of P factor of study area (a) 2007 and (b) 2017.



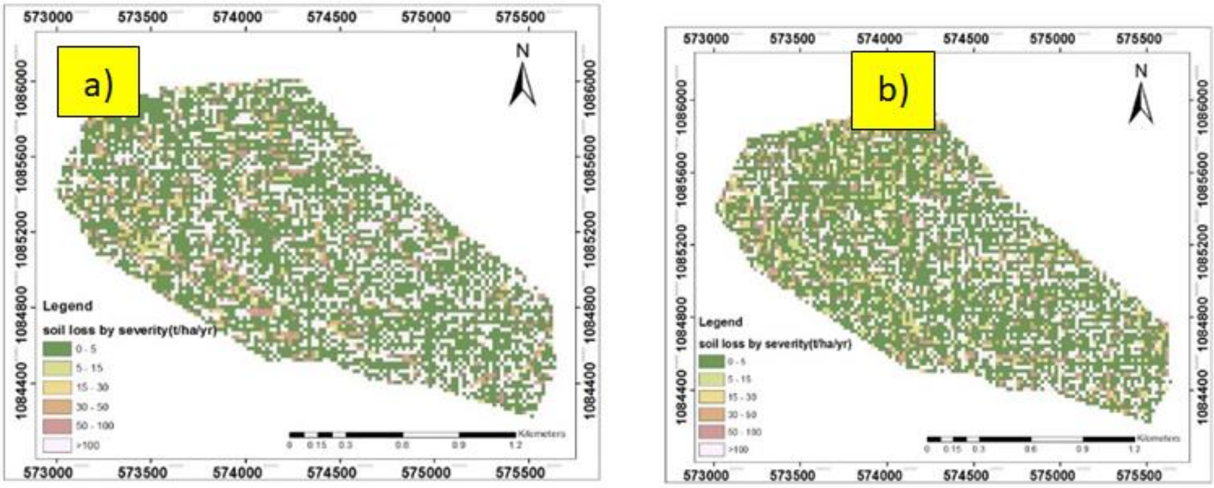
Soil loss

The mean average soil loss assessment in study watershed in 2007 and 2017 was estimated based on the principles of USLE model, which multiplies the five parameters. This computation was made by using raster calculator of ArcGIS spatial analysis action, which enables the cell by cell multiplication of the parameters.

Based on the analysis, the mean estimated annual soil loss rate of the watershed was found to be 26.68 t ha^{-1} yr^{-1} in year of 2007 and 14.07 t ha^{-1} yr^{-1} in 2017. The result clearly indicated that the average soil loss estimated during the two years have a significant difference due to land use change and applied SWCP in the watershed.

This result, agreed with previous study reports for example, average soil loss rate of 9.63 t ha^{-1} yr^{-1} in Medego watershed in the northern highlands; 9.10 t ha^{-1} yr^{-1} in Zingin watershed; 8.25 t ha^{-1} yr^{-1} in Ajima watershed. The result obtained in 2007 was also comparable with previous results although not well agreed, for example; Amsalu and Mengaw, estimated soil loss 30 t ha^{-1} yr^{-1} from Jabi Tehinan district, Estifanos, in 2014 estimated 39.8 t ha^{-1} yr^{-1} from Ribb Watershed and Gelagay and Minale estimated 47.4 t ha^{-1} yr^{-1} from Koga watershed in the upper blue nile basin and Mekonnen and Melesse, estimated a soil loss rate ranging from 12.5 t ha^{-1} yr^{-1} to 50 t ha^{-1} yr^{-1} at Debre Mewi watershed using RUSLE model (Figure 6).

Figure 6. Map showing the rate of soil loss at study area (a) 2007 and (b) 2017.



Soil loss estimation using Erosion pin method

The overall average soil BD based on laboratory results of the collected soil samples, was found to be 1.03g/cm³. The changes in heights of erosion-pins that were driven at three different sites of the watershed area were measured and recorded after every erosive rain until September 07, 2017. The average soil loss was estimated to be 16.26 t ha^{-1} yr^{-1}. This result agrees with 22.72 t ha^{-1} yr^{-1}.

In this study USLE model estimated soil was 14.07 t ha^{-1} yr^{-1} and the field measured soil loss was 16.26 t ha^{-1} yr^{-1}, were found to be comparable. Therefore, the estimated soil loss result is acceptable and the model can be used to estimate soil loss in the study area and other similar watershed having similar characteristics.

Soil loss tolerance

According to Ayenaw, the acceptable soil loss tolerance limits was classified in the range of 2-11.2 t ha^{-1} yr^{-1} in Ethiopia, based on the soil depth. From the USLE result 67.3% (189.7 ha) of the watershed area was under the tolerable limit value. However, before SWCP implementation (the year 2007), it was only 41.7% (117.6 ha) areas that are below the tolerable soil loss limit. This indicate 25.6% (72.1 ha) of the watershed's area was changed to the tolerable soil loss limit due to the application of SWCP. This an indication that the implemented SWCP were effective in reducing soil loss from the watershed (Table 4).

Table 4. Permissible soil loss (t ha^{-1} yr^{-1}) for each soil depth in Gina-beret watershed.

Permissible soil loss t ha^{-1} yr^{-1}	Soil depth (cm)					Area (ha)
	0-25	25-50	50-100	100-150	>150	
0-2	164.9					164.9
2-5		33.3				33.3
5-7			7.3			7.3
7-9				4.93		4.93
9-11					8.03	8.3

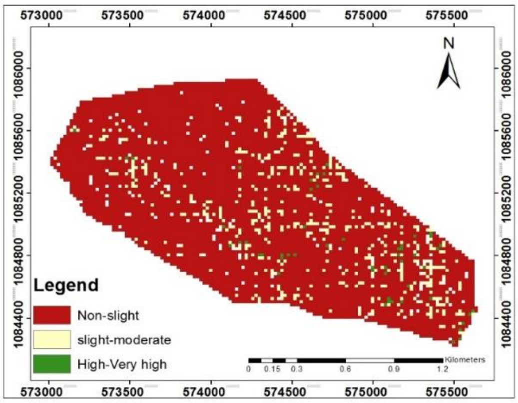
Area of tolerable loss (ha)	164.9	33.3	7.3	4.93	8.03	218.73

Table 4 shows, the maximum tolerable soil loss tolerance was 9-11 t ha^{-1} yr^{-1} with the corresponding area coverage of 8.03 ha in the deeper soil depth range. The majority of the watershed has soil loss tolerance 0-2 t ha^{-1} yr^{-1} with corresponding area coverage of 164.9 ha. Even though the implemented SWCP has brought significant reduction in soil loss rate, the overall watershed average soil loss rate was found still greater than the tolerable limit. This situation indicates that additional efforts are required to reduce the soil loss rate below the permissible limit through identification of erosion hot spot areas.

Erosion hazard map

Erosion hazard zone was analyzed based on the classified severity classes (Figure 7). In the result it was revealed that 60.2% (169.88 ha) of the watershed was categorized under none to slight erosion hazard zone. Besides, 7.02% (19.82 ha) was categorized under slight erosion hazard zone; 5.34% (15.07 ha) slight to moderate; and 6.76% (19.06 ha) under moderate range. The remaining 20.68% (58.17 ha) area of land was classified under high to very high erosion hazard zone.

Figure 7. Soil loss severity at Gina-Beret watershed central Ethiopia.



As indicated in Table 5, the watershed area was categorized in to the erosion hazard/severity class. Moreover, priority class were also indicated so as to assist decisions on the required efforts to apply SWCP. Therefore, more planning and development attention is required to be given for class I to IV to reduce the actual overall higher soil loss below the tolerable limit. The other part of the watershed was found to be strengthen by stabilization and maintenance works.

Table 5. Erosion hazard areas based on the severity class and soil loss range in Gina-Beret watershed.

Soil loss (t/ha/yr)	Severity class	Priority class	Area (ha)	% of coverage
0-5	Non-slight	VI	169.88	60.2
5-15	Slight	V	19.82	7.02
15-30	Slight-mod	IV	15.07	5.34
30-50	Moderate	III	19.06	6.76
50-100	High	II	15.34	5.49
>100	Very high	I	42.83	15.19

Determination of soil erosion hot spot areas

To determine erosion hot spot areas, the watershed was classified into three sub-watersheds, Tela Meshech, Feleko and Geda (Figure 8). Accordingly, the estimated average sub-watershed soil loss rates are presented in Table 6. Thus indicated that average soil loss rate for the classified sub-watersheds were found to be from 13.8 t ha^{-1} yr^{-1} to 22.28 t ha^{-1} yr^{-1} with standard deviation of 38.8 to 63.08. This indicates Tela-Meshecha sub watersheds have much soil loss, which could be given first priority, Feleko sub watershed could be given second stage of priority and Geda sub watersheds comes to last stage of priority during interventions.

Figure 8. Sub-watershed map of Gina-Beret watershed for erosion severity class.

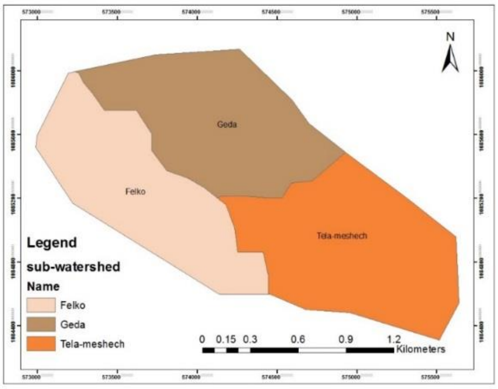


Table 6. Soil loss rate by subwatershed.

Subwatershed	Area (ha)	Soil loss rate (t $ha^{-1}yr^{-1}$)			
		Minimum	Maximum	Mean	SD
Tela Meshecha	102	0	793.001	22.28	63.08
Feleko	94	0	903.08	18.66	59.9
Geda	86	0	574.018	13.8	38.8

Soil lose by land cover/use types

Soil erosion rates were also computed across land cover/use types of the watershed (Table 7). The majority proportion (81.2%) of the soil loss was resulted from the cropland cover. This result is due to the absence of adequate ground cover in agricultural lands during the first rainy month coupled with lack of conservation practices. Soil loss is relatively high (14.59%) on the grazing lands next to cropland. Animal overgrazing associated with no management for grazing land was assumed to contribute for the significant erosion problem in the grazing lands. This results agreed with the findings of Hurni and Mulatie.

Table 7. Soil loss rate by land use/land cover.

Land use type	Soil loss rate in t $ha^{-1}yr^{-1}$							
	0-5	5-15	15-30	30-50	50-100	>100	Grand total (ha)	%
Crop land	161.14	19.72	14.33	11.32	11.01	11.07	228.59	81.2
Grazing land	29.6	3.13	2.8	2.32	2.06	1.25	41.15	14.59
Plantation	7.02	1.01	0.42	0.36	0.28	0.1	9.19	3.26

Built up area	0.36	0.03	0.03		0.04	0.01	0.46	0.16
Degraded land	2.36	0.12	0.07	0.01	0.04	-	2.61	0.92
Water body	-	-	-	-	-	-	-	-
Grand total (ha)	200.48	24.01	18.05	14.01	13.432	12.43	282	100
%	71.1	8.5	6.4	5	4.8	4.4	100	

Soil lose by slope class

Since slope is one of the critical erosion factors, Mekonnen and Melesse, soil loss rates were compered across slops ranges of the watershed (Table 8). The highest proportion of the soil loss (40.7%) was found in the slope gradient range of 15%-30%. Moreover, the larger area coverage in soil loss (80.14 ha) was found in the slope (15%-30%) and soil loss rate (0 ha^{-1} yr^{-1} to 5 ha^{-1} yr^{-1}) combination. Besides, 71.10% of the study watershed is from none to slight rate. Mekonnen and Melesse, Hailmarkos and Samuel also found that soil loss increase with an increase in slope gradient.

Table 8. Soil loss rate with slope class.

Slope class (%)	Soil loss rate (t $ha^{-1}yr^{-1}$)							
	0-5	5-15	15-30	30-50	50-100	>100	Grand total (ha)	%
0-3	7.66	1.06	0.27	0.14	0.23	0.13	9.49	3.4
3-8	30.65	6.03	2.96	1.69	1.26	0.44	43.02	15.3
8-15	56.73	9.45	5.58	4.38	2.77	1.06	79.95	28.4
15-30	80.14	6.99	8.27	6.52	6.45	6.46	114.83	40.7
30-50	21.92	0.48	0.94	1.24	2.51	3.53	30.62	10.9
>50	3.39	0	0.04	0.04	0.23	0.81	4.5	1.6
Grand total	200.49	24.01	18.06	14.01	13.45	12.43	282	100
%	71.1	8.51	6.4	4.97	4.77	4.41	100	

CONCLUSION

The purpose of this study was to analyze the status of soil erosion using USLE and Erosion pin method, to evaluate the effectiveness of soil and water conservation practices and identification of erosion hotspot area in Gina-Beret watershed. In the study watershed, the average soil loss was found to 16.26 t ha^{-1} yr^{-1} (using erosion pin); 14.07 t ha^{-1} yr^{-1} using USLE model after SWCP and 26.68 t ha^{-1} yr^{-1} before SWCP implementation. This shows that SWCP reduced the rate of soil loss by 12.41 t ha^{-1} yr^{-1} within 10 years. Hence it could be possible to conclude that SWCP played a substantial role in reducing soil loss in the study watershed.

Moreover, from the five erosion factors Rainfall (R), conservation management factor (P), land use/cover factor (C) and topography factor (LS) were found to be the dominant factors in promoting soil erosion in the watershed. The effectiveness of the SWCP was confirmed through modeling, field measurement and interview of farmers that soil loss decreasing within 10 years.

The majority of the watershed area falls under tolerable soil loss limit. Only 63.27 ha (22.44%) were above tolerable limit. More than 9.01% of the watershed areas were characterized by high to very high soil erosion hazard zone. Therefore, it should be given special priority to reduce or control the rate of soil erosion by means of proper soil and water conservation. On the other hand, non to moderate erosion hazard zone was (57.2 ha) should be protected from further erosion.

RECOMMENDATIONS

The findings of the study showed that almost all farmers of the study area had moderate perception on the causes, indicators and problems of soil erosion. The main constraints for better conservation activities were mainly related to limited farmer's awareness, lack of sense of ownership and sustainability issue and free grazing problem. Farmers have understood SWC measures are very helpful for erosion control. But not all SWC in the study area were effective because it was not maintained sustainably and open grazing. Farmers also need support by government or NGOs for the construction and maintenance of SWC structures. This dependence was influence the adoption and sustainability of the technology.

To reverse the problem of soil erosion from the study watershed integrated watershed management (physical and Biological SWCP) works will be done in standardize type with in short period of time. Soil management practices will incorporate with in planning for improvement of soil fertility as well as decreasing the detachability of soil for rainfall. To decrease the rainfall erosivity power on bare land leave the residual of cops in cultivated lands according to the priority of erosion risk areas.

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