#7880 SPATIAL SOIL LOSS RISK ASSESSMENT FOR PROPER INTERVENTION: A CASE OF NERI WATERSHED OMO-GIBE BASIN SOUTHWESTERN ETHIOPIA

Abebe Hegano[1*], Awdenegest Moges[2], and Nigatu Wonderade[2]
[1]Southern Agricultural Research Institute (SARI), PO Box 06, Hawassa, Ethiopia
[2]Hawassa University, Institute of Technology, PO Box 05, Hawassa, Ethiopia
abehegeno@gmail.com

ABSTRACT

Soil erosion is one of the biggest global environmental problems resulting in both on-site and offsite effects. It contributes negatively to agricultural production, quality of source water for drinking, ecosystem health in land and aquatic environments, and aesthetic value of landscapes. This study was conducted in Neri watershed, part of Omo Gibe basin with area of 465.46 km^2. RUSLE model supported by a GIS framework is used to assess the average annual soil loss, and create a soil erosion hazard map. To this end, data for the model parameters were derived from, a Digital Elevation Model (30*30 m), thirty years (1988-2017) rainfall data at 4 rain gauge stations, soil erodibility data from field samples, Landsat-8 satellite image for cover management and support practices. As result, the estimated average annual soil loss in Neri watershed varied from 0 at flat lands to 465.16 t ha^{-1} yr^{-1}at worst condition, with an estimated mean annual soil loss of 9.955 t ha^{-1} yr^{-1} and total amount of soil loss is 463365.46 t yr^{-1} About 54.88% (25536.8 ha) of the watershed was categorized below moderate classes. The remaining 45.12% (21009.2 ha) of land area was classified under high to very high classes about several times the maximum tolerable soil loss. Based on the soil loss hazard map, six sub-watersheds out of eleven Neri sub- watersheds need prior intervention in terms of integrated cover-management and mechanical conservation measures. Furthermore, RUSLE results can be refined by analyzing along with sub-watersheds level real time monitoring for conservation practices.

Keywords: soil erosion, RUSLE, GIS, Neri watershed, Ethiopia

INTRODUCTION

Soil erosion is the one among major threats to the sustainability of environment and productive capacity of agriculture (Yang et al., 2003; Feng et al., 2010), which makes plant root depth shallow, removes plant nutrients and losses water (Mahmud et al., 2005). This possibility can be attributed to the fact that the impact of soil erosion is more damaging on bare land and cultivated land than any other types of land use/land cover. A 17% productivity reduction in the global scale since the end of world war second (Angima et al., 2003). It results in serious food insecurity in many developing countries as it depletes productive soils (Blanco and Lal, 2008). The severe situation in Ethiopia is quantified by loss of 1 billion USD per year (Sonneveld, 2002) and is still affecting 50% of the agricultural area. It is the prime contributor to temporary or permanent decline of the productivity of land (Oldeman et al., 1991). Its effects are also recognized to be severe threats to the national economy of Ethiopia (Tamene, 2005).

Soil loss by surface runoff is a severe ecological problem occupying 56% (1,100 million hectares) of the world-wide area as accelerated by human-induced soil degradation as (Bai et al., 2008). In the same manner, about 43% (537,000 km2) of the total highland areas of Ethiopia are highly affected by soil erosion (Hurni, 1990).

Quantitative understanding of soil loss has got attention of scientific community in different parts of Ethiopia. For instance, in the Ethiopian highlands only, an annual soil loss reaches 200-300 tons ha-^{1}yr^{-1} (FAO, 1984; Hurni, 1993) and soil loss due to erosion in Ethiopia amounts to 1493 million tons per annum, of which about 42t ha^{-1} yr-^{1} was estimated from cultivated fields of Ethiopia (Hurni, 2008).

The study area, Neri watershed, lower part of Omo Gibe basin in South Omo zone, obviously shares the above-mentioned hazards and threats of soil erosion. Despite all these all these could not go beyond quantified risks of soil loss and its spatial distribution for prioritized intervention, there was no area specific information investigated particular to this watershed.

Consequently, this study is aimed to assess the average annual soil loss, and create a soil erosion hazard map within this watershed is needed for decision makers in policy and strategy formulation and, for natural resource managers by providing a necessary tool to design the right intervention strategy for the specific climate, soil type, and topography and land use situation.

MATERIALS AND METHODS

Soil erosion modeling study was conducted, Neri watershed is situated in the lower part of the Omo Ghibe basin southwestern, Ethiopia. Geographically, it lies between 5.63^{0} and 5.93^{0} North, and 36.31^{0} and 36.67^{0} East. The study area is about 465.46 km^{2}.

RUSLE empirical model Renard et al. (1997) supported by a GIS framework is used to assess the average annual soil loss, and create a soil erosion hazard map. To this end, data for the model parameters were derived from, NMA thirty years (1988-2017) rainfall data at 4 rain gauge stations, soil erodibility data from field samples, Landsat-8 satellite image (OLI) assessed online USGS on 1st January 2017, for cover management and support practices. The RUSLE (Renard et al., 1997) model can be expressed as Equation (1);

$$\mathrm{A} = \mathrm{R} * \mathrm{K} * \mathrm{LS} * \mathrm{C} * \mathrm{P} \text{...... ....Equation 1}$$

Where, A, stands for computed soil loss per unit area per year (t ha^{-1} yr^{-1}), R for rainfall erosivity factor (MJ mm ha^{-1} h^{-1}yr^{-1}), K for soil erodibility factor (t ha MJ^{-1} mm^{-1}) , LS for slope length and steepness factor (dimensionless), C for cover - management factor (dimensionless) and P for support practice factor (dimensionless) R factor was determined using regression (Equation 1) calibrated by (Kaltenrieder, 2007).

$$R = (0.55 * P) - 4.7 \text{..Equation 2}$$

Where, R is rainfall erosivity factor, P is mean annual rainfall in (mm)

Soil erodibility (K-factor) has been calculated after textural (analysis particle size distribution) by means of the following formulae which were developed from global data of measured K values, obtained from 225 soil classes (Renard et al. 1997).

$$K = \{0.0034 + 0.0405\exp\left[\frac{-1}{2}\left[\left[\frac{\log(\mathrm{Dg})+1.659}{0.7101}\right]2\right\} \text{..............................Equation 3}$$

$\mathrm{Dg} = exp\left(\sum fi \ln\frac{(di+di-1)}{2}\right)$ With R^{2} = 0.983 Where, Dg is the geometric mean particle size, for each particle size class (clay, silt, sand), d_i is the maximum diameter (mm), d_{i-1} is the minimum diameter and f_i is the corresponding mass fraction.

LS-factor was computed from ASTER DEM by ArcGIS 10.3.1 in raster calculator using the map algebra expression in (Equation 4) suggested by Mitasova and Mitas (1999)

$$LS = pow\left(\left[flowaccumulation\right] * {}^{cellsize}/_{22.13}, 0.6\right) * pow(\sin([slope] * 0.01745)/0.0896, 1.3)$$

…………………………………………………………………………………..Equation 4

C-factor estimation was done by two maps generated (LULC and NDVI suggested by Durigon et al.(2014) and regression equation (Equation 5) obtained for this particular study watershed from C-factor tabular values of references and NDVI map was employed.

$C= -1.211*(NDVI) + 0.615$ ……………………………………………Equation 5

P-factor was obtained from both slope and LULC classes (Wischmeier and Smith, 1978) because no soil conservation practices. So, conservation practices vary based on LULC and slope.

RESULTS AND DISCUSSION

Revised Universal Soil Loss Equation Model Individual Factors Outputs

Rainfall erosivity values as result of Inverse distance weighted (IDW) interpolation, range from 713.1 to 754.43 $MJmmh^{-1}ha^{-1}yr^{-1}$ with mean of 731.87. As the result of kriging interpolation of calculated spatial K-values based on equation (11) and (12). K-factor values in the study watershed differed from (0.0306 – 0.044) Mg h MJ^{-1} mm^{-1}. Estimated annual average soil erodibility factor was 0.0385Mg $hMJ^{-1}mm^{-1}$. As result of linear regression equation, C-factor output was found to its maximum value of 0.6141, minimum 0.01056 and average 0.385 and the P factor values of study area ranges between 0.11 and 1 with mean of 0.591.

Soil Loss Estimation Results

The RUSLE model output pixel level analysis result of Neri watershed ranges from in the mean (0-465.16 ton $ha^{-1}yr^{-1}$) the maximum amount estimated at the mid-eastern parts of the watershed. The very high pixel values (more than 25 tons $ha^{-1}yr^{-1}$) were detected in a distributed manner throughout the watershed. However, the particular maximum pixel value found at much of the steeper slope banks with high LS factor value where poor surface cover condition. The average annual soil loss rate is 9.955 tons $ha^{-1}yr^{-1}$ from the entire watershed area (46546 hectare). The total amount of soil loss is 463365.46 tons yr^{-1}.

The mean annual soil loss rate from this watershed is higher than the previous research report compared with the case of Gibe-III Dam Catchment which is 7.47 t /ha/ y by Gera work and Awdenegest (2014). Conversely, the mean annual soil loss results of current study is lower than the annual average soil loss under Ethiopian condition which is 12 tons per hectare per year and about $42tha^{-1}yr^{-1}$ from cultivated highland (Hurni, 1993) could be due to agricultural fields lie less slopes.,

According to WBISPP (2001), the average annual soil erosion rates were classified into the five priority classes, namely, 'Very Less (0-03.125), Less (3.125-6.25), High (12.5-25) and Very high (>25) t ha^{-1} yr^{-1} to develop soil erosion severity maps.

Table 1. Area and amount of annual soil loss for each severity class (WBISPP, 2001).

Soil loss (t ha^{-1} year^{-1})	Equivalent top soil removal (mm)	Soil loss risk class	Area (ha)	Area (%)
(0 - 3.125)	(<0.2.5)	Very Less	25023.13	53.76%
(3.125 - 6.25)	0.2.5 – 0.5	Less	6316.29	13.57%
(6.25 - 12.5)	0.5 - 1	Moderate	10896.42	23.41%
(12.5 - 25)	1 - 2	High	3025.49	6.5%
(> 25)	>2	Very High	1284.67	2.76%
			46546	**100%**

As result, about more than 6.25 tons ha^{-1}yr^{-1}, was (19,241ha.), which comprises 32.67% of the total study area which zone of a great danger of soil erosion and the remaining 67.33%, (31339.42) hectare is lesser, which is recognized as not.

Prioritization of Intervention areas

According to (Gebreyesus and Kirubel, 2009; FAO and UNEP., 1984), soil loss tolerance (SLT) denotes the maximum allowable soil loss rate that will sustain an economic and a high level of productivity. (WBISPP, 2001) classification of soil loss classes which is for Southern Ethiopia was used, which is more than tolerable loss rate category (>6.125 t ha^{-1} year^{-1} As result, 7 sub watersheds out of eleven and or 9 kebeles out of 19 were beyond this soil loss tolerance rate.

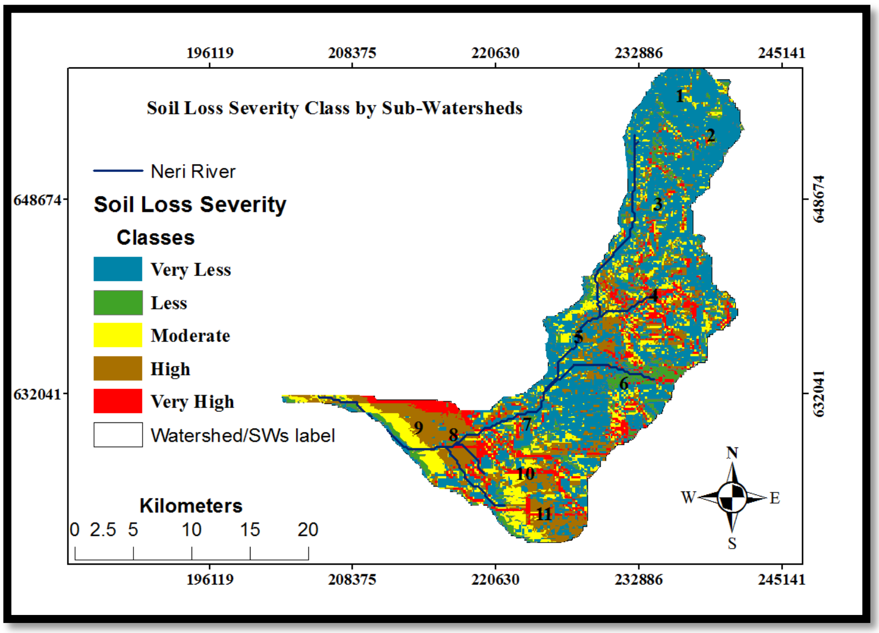

Figure 1. Soil loss severity classes by sub watershed.

CONCLUSIONS

The application of RUSLE model with the aid of GIS and remote sensing was applied over the Neri watershed to generate soil loss hazard map. Moreover, the study was an attempt to estimate average annual soil loss at this watershed and to identify risky areas priority intervention. The soil loss map produced by overlaying of grid maps of the six factors showed that the soil loss rate of the watershed ranged from (0 – 465.16 t ha-^{1}yr^{-1}) with a mean annual soil loss rate of 9.95 t ha-^{1}yr-^{1} and overall total annual amount of 463,365.46t/yr. So that, it is perceptible that this watershed is under risk of soil erosion.

As a further matter, for the prioritization of intervention, the soil loss map of baseline period was used to extract the soil loss per nineteen (19) kebeles administrative units and eleven (11) sub-watersheds (SWs). But sub-watersheds having greater than SLT were chosen. Based on the analysis, sub-watersheds greater than SLT in their order of area weighted average soil loss were identified for priority intervention. Based on the findings of this study, to ensure sustainable resource use, management practice by strong policy measures, erosion minimization in agricultural and non-agricultural land use classes are of paramount importance

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