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ASSESSMENT OF SOIL EROSION RISK IN KAMSHTY WATERSHED OF NORTH ARI DISTRICT, SOUTH WESTERN ETHIOPIA

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ABSTRACT

Soil erosion is part of land degradation that affects physical and chemical properties of soil and land productivity, which is resulted from inappropriate land use practices. The purpose of the study was to assess the current status of physical and chemical properties of soil, and quantified the rate of soil loss and map of erosion risk areas in Kamshty watershed. The Universal Soil Loss Equation Model and Geographic Information Techniques were used to quantify mean annual soil loss and map in the area. The composite soil samples were collected at 0-30 cm soil depth and the laboratory analysis has been seen as the physical and chemical properties of soil are significantly decreasing in the watershed. All of the analyzed soil properties were significantly ($P<0.05$) in the watershed except organic matter, total nitrogen, and cation exchange capacity. The soil loss in the study watershed area ranged between 0-260.45 t ha^{-1} $year^{-1}$ with mean annual soil loss rate of 26.04 t ha^{-1} $year^{-1}$. In the watershed area low to moderate erosion risk areas are highly concentrated in southern and central-east and west parts, whereas high to severe erosion hazardous areas are focused in the intensively farming hilly northern, central, and central-west areas. In the study area (34.9 %) is categorized under high to sever erosion risk area with soil loss rate ranged between 14.29-260.45 t $ha^{-1}$$year^{-1}$.Hence, large area of the watershed should be implemented soil and water conservation measures.

Keywords: Watershed, Erosion risk area, Physical and chemical soil properties, Universal Soil Loss Equation, Geographic Information System.

INTRODUCTION

Soil is the basic resource for economic development and for maintaining sustainable productive landscapes and people's livelihoods especially for countries with agrarian economy like Ethiopia. As studied by FAO (2004) humans obtain more than 99.7% of their food (calories) from the land and less than 0.3% from the oceans and other aquatic ecosystems, preserving cropland and maintaining soil fertility should be of the highest importance to human welfare. However, due to mismanagement by human being, there has been a continuous deterioration of nutrient soil throughout the world. Indeed, nowadays in spite of its importance soil erosion is one of the most serious threat problems affecting the wellbeing of the human beings and disturbing the global environmental sustainability in general (Mebrahten, 2014).

Soil erosion can be caused by geomorphologic process, but accelerated soil erosion is principally favored by human activities. It is clearly evident that the ultimate cause of soil erosion is human himself contributing about 60% to 80% of all soil erosion and soil degradation (McNeill, 2000). As stated by Reusing *et al.* (2000) that cultivation without using specific control techniques and unplanned land use, and related issues, such as rapid population growth, deforestation, intensive land cultivation, uncontrolled grazing and higher demand for firewood often cause soil erosion in the world principally in developing countries. Basically soil loss is activated by an amalgamation of factors such as slope length and slope steepness, climate change, land cover patterns and the intrinsic properties of a soil, which makes the soil particles more prone to erosion. From the above view points, the soil factors such as texture, structure, organic matter content, permeability and land use management systems are also important in deciding soil erodibility (Wischmeier and Smith, 1978).

Ethiopia has a total surface area of 112 million hectares; of which 60 million hectares is estimated to be agriculturally productive., out of the estimated agriculturally productive lands, about 27 million hectares are significantly eroded, 14 million hectares are seriously eroded and two million hectares have reached the point of no return, with an estimated total loss of two billion m3 of top soil per year (FAO, 1984). Similarly, the total soil loss by erosion from all land is an estimated 1.9-3.5 billion tons of topsoil in Ethiopian highlands has been lost, which has an economic cost of soil erosion is around US$ 1 to 2 billion per year is being eroded every year (EFAP, 1993). But the experiments conducted by Hurni (1990) reported the average annual soil loss of 42 t ha^{-1} y^{-1} from cultivated land. As a result, soil organic matter has declined, soil nutrients depleted, and soil depth decreased leading to the decline in yield of crops and forages in most parts of Ethiopia (Paulos, 2001). In this regard, nowadays poverty and food insecurity are concentrated in rural areas ((MoARD, 2010). Thus, currently nearly 66% of the world population is malnourished due to inadequate intake of nutrients and per capita food production has been declined (WHO, 2004).

Kamshty watershed has been affecting by sever soil erosion especially in sheet and rill erosion. It is characterized by overpopulation, deforestation, land use/land cover changes, expansion of crop cultivation on steep slopes, and lack of sustainable use of natural resources. Therefore, the study area has been seriously threatening the productive agricultural lands and affecting the natural resources. Hereafter, if the problem persists and may not be solved, in the future will happen indefinitely extremely on-site and off-site effects such as the reduction of agricultural production, formation of gully erosion, sedimentation and siltation, resettlement, and totally in the quality as well as quantity of fertile agricultural lands and water development will decline.

ISSN: 2455-6939

Volume:04, Issue:04 "July-August 2018"

This problem may make the people in the watershed to be food in secured. However, to undertake effective soil and water conservation measures on severely deteriorated watershed areas, the availability of soil erosion risk map is very essential. Therefore, this scenario has initiated the researcher to launch the study. This research has given answers to three core research objectives; to assess the current status of physical and chemical soil properties, to quantify the mean annual rate of soil erosion risk, and to develop map of soil erosion risk areas in Kamshty watershed.

2. MATERIALS AND RESEARCH METHODS

2.1 Description of the Study Area

The study was conducted at Kamshty watershed, North Ari District, south western Ethiopia. The district of watershed is bordered with Uba Debretsehay District in the East, Basketo special District in the West, Geze Gofa and Oyida Districts in the North, and South Ari District in the South. It lies between 6^0 10′0″ N to 6^0 14′ 0″N and 36^0 40′ 0″E to 36^0 42′0″E latitudes and longitudes, respectively (Fig. 1). The total area of Kamshty watershed was 3,913 ha; of which about 1,796 ha dominated by greater than 30 % slope. The altitude of watershed is ranged from 1383 to 2990 meters above sea level. The mean annual rainfall of the watershed ranges from 876-1763 mm/year. Similarly also, the mean annual temperature ranged from 11.3 ^{0}c to 22.3 ^{0}c.

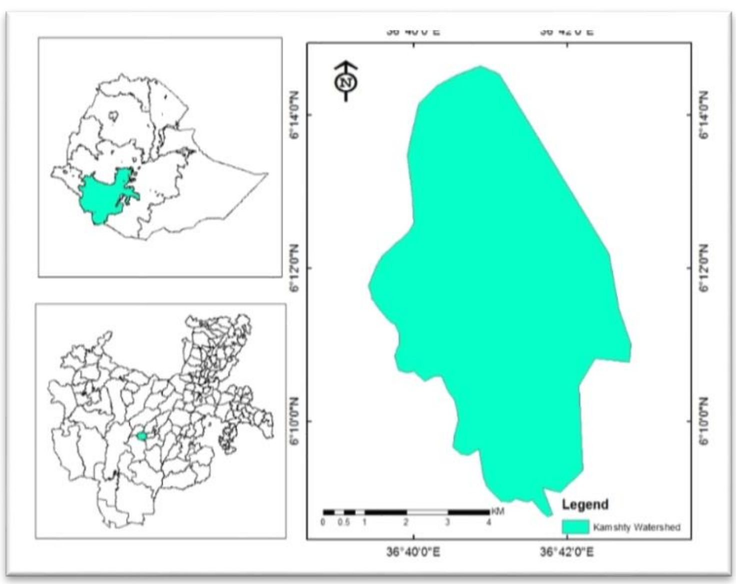

Fig 1: Location map of Kamshty watershed

Vertisols and Nitosols in the upstream and midland, respectively, whereas Fluvisols in the downstream are the main soil types. The total population of the watershed was about 9,045 of which 4,955 (55 %) male and 4,090 (45 %) female). Kamshty watershed has a drainage system characterized by perennial and seasonal rivers, which are tributaries of Yirgino River, in which this is direct flow to Omo-Gibe River Basin. Agriculture and livestock keeping are therefore the most important livelihood assets, but off farm activities are also carried out during the off farming seasons. Some of the dominant seasonal and annual crops and different varieties of fruits that are produced in the watershed include maize (*Zea mays*), teff (*Eragrostis tef*), cassava (*Manihot esculenta*), barley (*Hordeum vulgare*), wheat (*Triticum vulgare*), bean (*Phaseolus vulgaris*), banana (*Musa mesta*), avocado and others in the area. Enset (*Ensete ventricosum*) is the most dominant staple food in the study area. The dominant land use/covers in the watershed are cultivated land, eucalyptus tree land, bamboo land, enset and grazing land.

2.2 Data Sources and Methods of Data Analysis

This study has both primary and secondary data sources. The primary sources of data were generated from field observation, topographic data, and soil samples. The secondary sources of data were meteorological data, satellite imagery, and other relevant materials. Topographic data of slope positions characteristics are derived from topographic map of 1:50,000 scale with 30 m contour lines of various heights are digitized and computerized in GIS environment for preparing digital elevation model (DEM), which was used to determine slope length (L) and slope steepness (S) factors. The land use/land cover data was collected by using a resolution of 30 m of Landsat satellite imagery which was used to detect the current crop cover management (C factor) and the soil losses expectation in each slope positions for a certain soil conservation practices (P factor), respectively. Ten years (2007-2016) mean annual amount of rainfall data was obtained from national meteorological station for computation of rainfall erosivity (R factor).

Composite soil samples were collected from three slope positions of watershed upper, middle and lower followed by different land use/land cover types and altitude features by using auger and GPS readings scientifically by zigzag line at 0-30 cm soil. Totally the researcher has collected 27 representative composite soil samples, which were dried and grinded for laboratory analysis for its physical and chemical properties (**Table 2 and 5**).The laboratory results were analyzed by using analysis of variance (ANOVA) to determine the significance of differences at ($P<0.05$) whether there is variation in soil properties or not in the watershed area. In addition to this also descriptive statistics were used to compare severity of soil erosion in the area.

3. RESEARCH METHODS

To assess mean annual soil loss and delineate erosion hazardous areas in kamshty watershed, in original or modified form of Universal Soil Loss Equation (USLE) together with Remote Sensing and Geographic Information System (GIS) was utilized (Wischmeier and Smith, 1978). Mathematically the equation is denoted as: A (tons/ha/year) = $R * K * L * S * C * P$

Where, A=calculated annual soil loss, R= Rainfall and runoff erosivity index, K=Soil erodibility factor, L=Slope length factor, S=Slope steepness factor, C=Cover management factor, and P=Conservation practice factor.

3.1 Soil Erosion Risk Factors used in USLE prediction

Rainfall Erosivity (R) Factor

The R-factor is defined as the detachment and transportation of soil due to raindrop impact and runoff, primarily depends on the intensity and the amount of rainfall. The erosivity factor (R) in this study was therefore calculated based on the equation given by Hurni (1985a) for Ethiopian conditions. The R-factor was derived from mean annual rainfall data due to the unavailable of rainfall kinetic energy and measuring of the rainfall intensity autographic recorders data in the study area. It is given as: $R= -8.12 + (0.562*P)$ where; R is the rainfall erosivity factor and P is the mean annual rainfall (mm/year). In order to calculate uninterrupted rainfall data three stations were taken from neighboring districts (Table 1). They were interpolated by inverse distance weighted (IDW) method so as to quantify the R-value of each grid cells. Thus, the quantified erosivity factor ranges from 800.59 to 1120.43 and the result of this interpolation gives us an idea that there is significant variation of erosivity value in the watershed (Fig. 2).

Table 1: Mean annual rainfall and the corresponding R-factor value

Station Name	Mean Annual Rainfall (2007-2016)	R-factor
Gelila	1680.84	936.5
Bulkimender	1592.67	886.96
Beto	1001.99	554.99
Gazer	1616.62	900.42
Laska	1400	778.68

Source: (NMA, 2016)

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Volume:04, Issue:04 "July-August 2018"

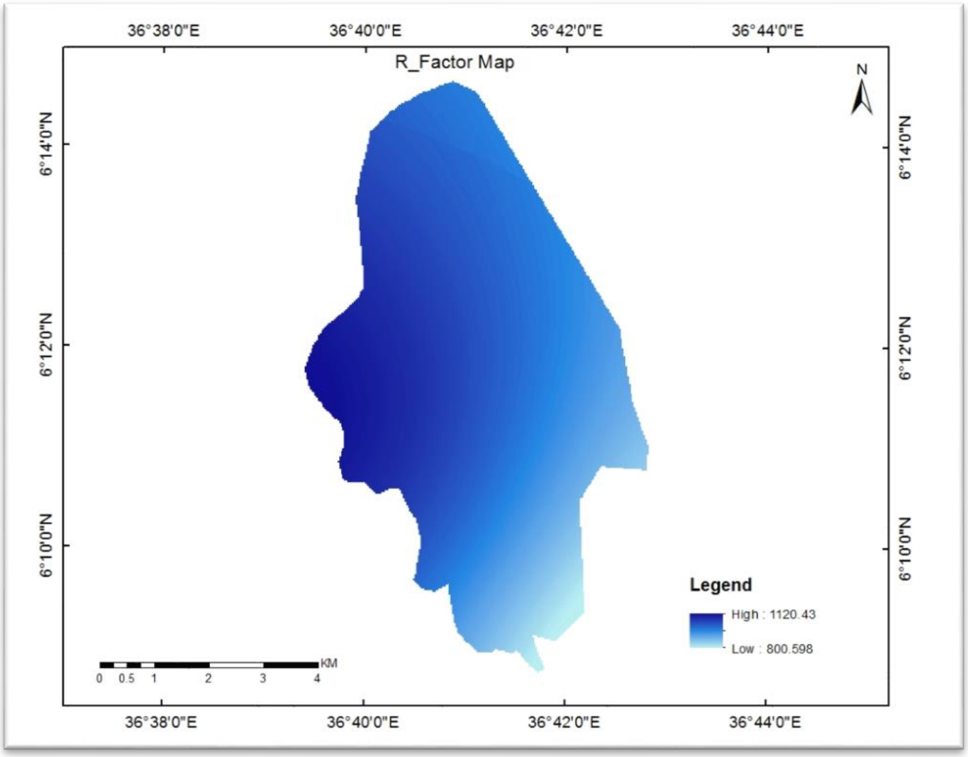

Fig 2: R-factor map of the Kamshty watershed

Soil Erodibility (K) Factor

Soil erodibility is the manifestation of the inherent resistance of soil particles for the detaching and transporting power of rain fall (Wischmeier and Smith, 1978). Thus, soil erodibility of tropical soils is highly dependent on the function of texture (on grain size distribution), organic matter (OM) content, permeability or water retention properties, land use management systems, and the physical and chemical properties of the soil, which contribute either to its erodibility potential or influence the stability of soil aggregates (Wischmeier and Smith, 1978). For this study, the soil erodibility factor units were calculated using the formula by (Wischmeier and Smith, 1978). The formula of soil erodibility (K factor)= (27.66/ $m^{1.14}$ * 10-8 (12-a)) + (0.0043 * (b-2)) + (0.0033 * (c-3)), in which K = soil erodibility factor (t_ha-1_MJ-1_mm-1); m = (silt (%) + very fine sand (%)) (100-clay (%)); a = organic matter (%); b = structure code: (1) very structured or particulate, (2) fairly structured, (3) slightly structured and (4) solid, and c = profile permeability code: (1) rapid, (2) moderate to rapid, (3) moderate, (4) moderate to slow, (5) slow and (6) very slow. 2235.8

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Volume:04, Issue:04 "July-August 2018"

After assigning K-factors of the study area, the developed map was converted to a grid map of 30 m cell size. Thus, the resulted soil erodibility value in the study watershed was ranged from 0.076 to 0.15 t*ha/MJ*mm (**Table 2**). The average soil erodibility value of the watershed was 0.118 t*ha/MJ*mm. Thus, according to Wischmeier and Smith (1978) K-factor class in the study area is considered to be very high erodibility index, which is greater than 0.066 t*ha/MJ*mm. As a result of this, we can understand below (**Table 2**) that the highest K-value soil is highly affected by erosion, whereas the lowest K-value has low soil erodibility. It is high in the south and central areas as compared to the northern margin of the study area (**Table 2**).

Table 2: Soil properties and their respective mean erodibility factor values

Soil Properties	Upper land	Middle land	Lowland
Silt (%)	11.8	13.8	25.5
Very Fine sand (%)	24.9	26.3	25.8
Clay (%)	63.3	59.9	48.7
Organic matter	2.45	1.88	2.28
Structure	3	3	4
Permeability	4	3	2
K value	0.15	0.128	0.076

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Volume:04, Issue:04 "July-August 2018"

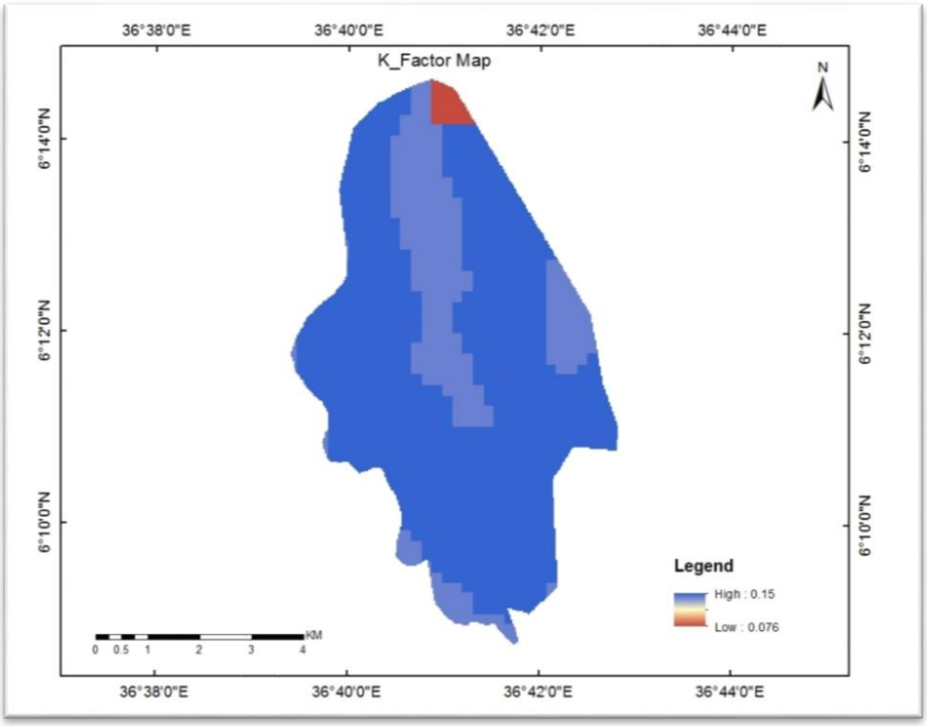

Fig 3: K-factor map of Kamshty watershed

Topographic Factor (LS)

The slope length and slope steepness factors are commonly combined in a single index as LS and referred to as the topographic factor, which influences flow velocity on the rate of erosion between the distance of origin and termination of inter-rill processes. Slope length is defined as the distance from the point of origin of overland flow to the point where either the slope gradient decreases enough that deposition begins or the runoff water enters a well-defined channel that may be part of a drainage network. In this study area, the LS factors could be quantified from a digital elevation model (DEM) by using the scale map 1:50,000. Thus, in this finding the best suited relation for integration with GIS grid is the theoretical relationship proposed by Engel (2005) based on the following equation below:

LS = ([Flow Accumulation] * [cell size] / 22.13)0.4 * (sin [local Slope gradient (degrees)] /0.0896)$^{1.3}$

Where, LS is slope length-steepness factor and cell size is 30m by 30 m unit contributing area. As expressed above (LS factor), the result of LS factor extends from 0 m in the lower part of the watershed to 14.52 m in the steepest part of the watershed (**Fig. 4**). This clearly show that the influence of the combined slope LS factor for soil loss is significant in the steepest part of the watershed.

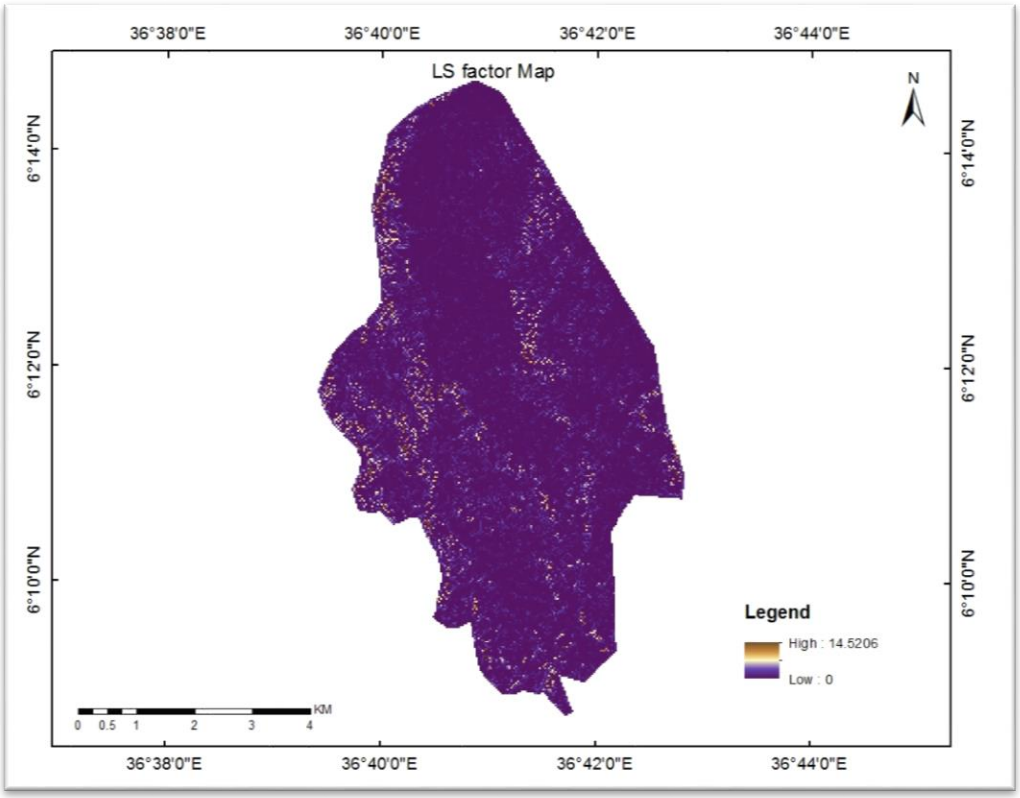

Fig 4: LS-factor map of Kamshty watershed

Cover Management Factor (C)

The C-factor measures the combined effect of all the interrelated cropping or vegetative cover and management variables in agricultural system and the effect of ground cover, tree canopy and grass covers in reducing soil loss in nonagricultural condition (Wischmeier and Smith, 1978). The effect of vegetation reduces soil erosion by protecting the soil against the action of falling raindrops, increasing the degree of infiltration of water into the soil, reducing the speed of the surface runoff, binding the soil mechanically, improving the physical, chemical and biological properties of the soil (De Asis and Omasa, 2007). The C-factor was obtained from different studies (**Table 3**) for Ethiopia condition using weighted value of the different land cover of the study area. The image classification was undertaken using both unsupervised and supervised image classification techniques. Thus, the values of the study watershed were ranging from 0.01

to 0.6, which was contradicting between 0.01-0.2 with the finding of Morgan (2005). Thus, this clearly show that there is significant factor from the cover management in the study area.

Table 3: Cover Management (C) factor values of the study area

Land use/land cover type	C- factor value	References
Cultivated land (cereals/pulses)	0.17	Hurni (1988)
woodland	0.06	Wischmeier and Smith (1978)
Bare land	0.6	BCEOM (1998)
Grass land	0.01	Hurni (1985a)

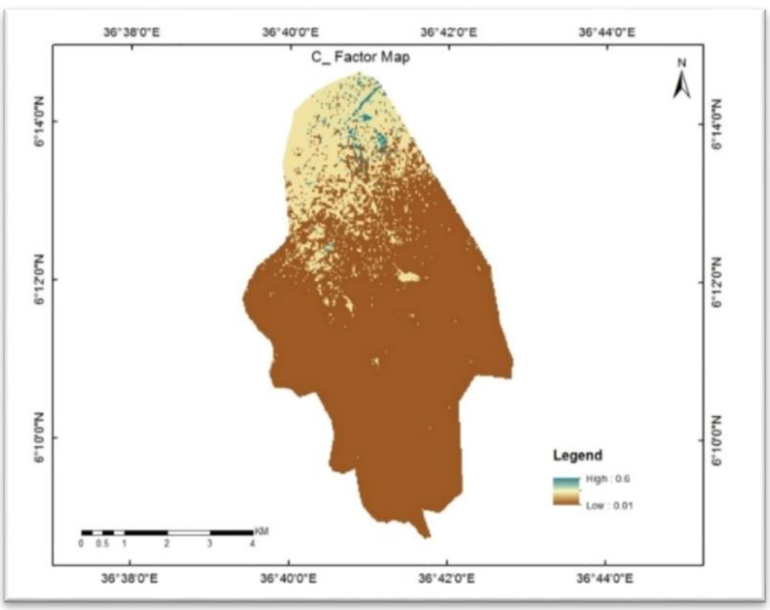

Fig 5: C-factor map of Kamshty watershed

Management Practice Factor (P-value)

The conservation practices factor (p-values) reflects the effects of practices that will reduce the amount and rate of the water runoff. The effectiveness of p-factor especially in agricultural areas would be enhanced by strip cropping, crop rotation, contour planting, cover cropping, managed grazing, residues, control structures and diversions, and terracing. They are important factor that can control the erosion and to maintain soil fertility and infiltration of water and organic matter. However, in the study area during the field observation and informal discussions with farmers

ISSN: 2455-6939
Volume:04, Issue:04 "July-August 2018"

confirmed that there was minimum soil and water conservation works undertaken. So this small soil erosion control measures resulted runoff speed in the study area.

To find the management factors, the researcher used the assigned considering local management practices along with values suggested for Ethiopian condition by Wischmeier and Smith (1978). They determined two land use classes namely agricultural and others and their slopes were used. The assigned P-values range from 0 to 1, where by the value 0 represents a very good manmade erosion resistance facility and the value 1 no manmade resistance erosion facility (**Table 4**). Thus, results indicated that most of other lands in the watershed is covered by grass land, bare land, bamboo land, eucalyptus land, wetland, and enset/banana land.

Table 4: Conservation Practice Factor (P-Value)

Land use type	Slope (%)	P-factor
Cultivated land	0– 5	0.1
	5– 10	0.12
	10 – 20	0.14
	20 – 30	0.19
	30 – 50	0.25
	50 – 100	0.33
Other land	All	1.00

ISSN: 2455-6939

Volume:04, Issue:04 "July-August 2018"

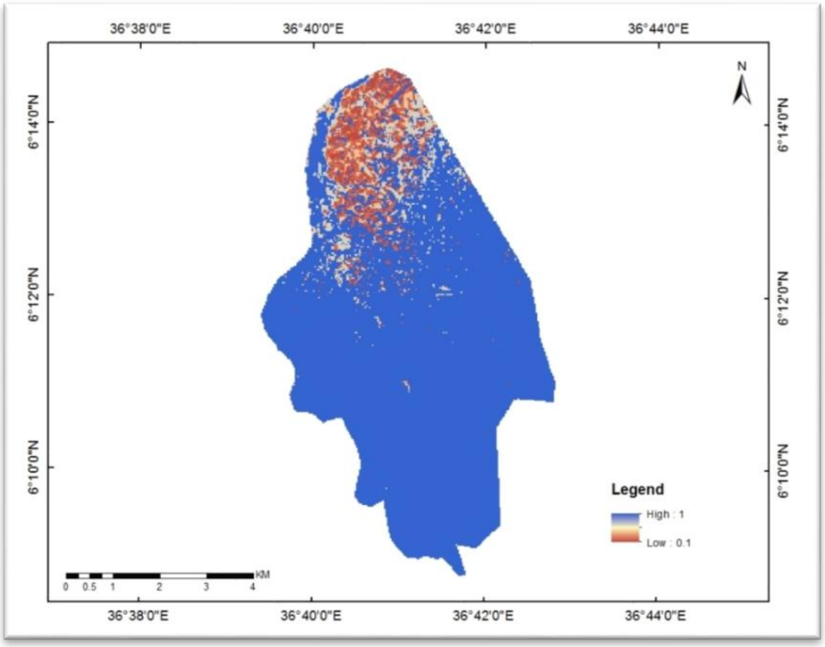

Fig 6: P-factor map of Kamshty watershed

4. RESULTS AND DISCUSSION

4.1 Physical and Chemical Soil Properties

Table 5: Laboratory result of soil sample in Kamshty watershed

	Upper land						Middle land				Lowland	
Soil property	En	Gr	Ba	Be	Bam	Eu	En	Be	Ba	Wh	Ma	Te
pH	5.00	5.14	4.81	5.05	4.67	4.78	5.28	5.02	5.22	5.14	6.05	6.22
Texture class	Clay	Clay	Clay sandy	Clay sandy	Clay	Clay	Clay loam	Clay sandy	Clay sandy	Clay loam	Clay loam	Clay loam
%OM	3.28	2.75	1.64	2.4	3.10	1.40	2.10	1.89	1.50	2.05	1.92	2.64
TN (%)	0.57	0.59	0.57	0.56	0.61	0.56	0.54	0.56	0.56	0.58	0.71	0.78

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Volume:04, Issue:04 "July-August 2018"

Av.P/kg	0.74	0.81	0.76	0.72	0.88	0.72	0.62	0.64	0.65	0.74	0.66	0.66
Av. K	160.02	82.14	105.08	163.68	111.12	136.4	244.48	186.6	219.73	179.64	203.04	194.46
CEC	34.82	43.62	39.65	36.88	39.98	40.79	38.85	35.01	39.88	42.56	43.72	43.35

Note: *Code of the land use types: En= Enset (ensete ventricosum); Gr= Grazing land; Ba= Barely; Be= Bean;*

Bam= Bamboo; Eu= Eucalyptus; Wh= Wheat; Ma= Maize, and Te= Teff

Soil Reaction (pH)

The lowest and highest pH values ranged from 4.67 to 6.22, respectively. The result of soil pH indicates that it is significantly different ($P<0.05$). The soil reaction value of the watershed was ranged from strongly acidic ($pH \leq 5.5$) to moderately acidic (5.6- 6.6) as per the rating suggested by (*Karltun et al.*, 2013). According to this suggestion, in the study area 83.3% soils are ranged under strongly acidic, whereas 16.7% samples are in moderately acidic status. The reason for this variability could be land use type and parent material, and high rainfall that results in loss of basic cations through leaching and drain to streams in runoff generated from accelerated erosion. According to the current result, the strongly acidic values of soil reaction revealed in the upland and midland of the watershed, whereas the remaining lowland category was fall under moderately acidic range.

Soil Texture

As noted in Table 5, present particle size distribution of soils in the study area is dominantly clay and clay sandy in upper and middle part of the watershed, whereas clay loam is dominantly in the low land area. The clay and slit soil particles were obtained varied significantly ($P<0.05$), while sandy soil particle is insignificant difference ($P<0.05$) among land use/land covers of the watershed. As revealed in field observation and laboratory analysis, the result difference in the watershed could be the effect of variation in parent material, slope positions, and cover management practices. Thus, soils in the study watershed area also differ in their susceptibility to erosion (erodibility) based on texture; a soil with a high percentage of silt and clay particles has a greater erodibility than a sandy soil under the same conditions.

Soil Organic Matter (SOM)

The soil OM contents in the watershed ranged from 1.4 to 3.28 % in the eucalyptus and enset cultivated lands, respectively (Table 5). There was insignificant difference (P<0.05) in OM values of the watershed soils. The reason of this variation might be due to variation in altitude, erosion, use of organic manure, grazing, residual removal, cropping system and soil management practices. When the top soil is removed by erosion, the clay content of the remaining soil increases and also this results the loss of soil fertility. Some research works have indicated that most of the productive agricultural soils have organic matters between 3% and 6% (Fenton *et al.*, 2008). According to this literature, different land use/land covers soil organic matter in the study area was not under the good status.

Total Nitrogen (TN)

As shown in Table 5, the total nitrogen (TN) content was highest (0.78 %) under the *teff* land and lowest (0.54 %) on the enset land. The result of TN in the watershed was insignificant difference (P<0.05) among different land use/land covers. On the basis of the rating suggested by Landon (1991) (Table 6), soils in all category of the watershed was rated as high in TN, but it is reaching to be low status (Table 5). The reason for this lowering might be the high amount of rainfall with drainage in the area that leads to leaching and decline in TN.

Available Phosphorus (Av. P)

The result of available P in the soils of the watershed ranged from minimum 0.62 to maximum 0.88 mg/kg in the enset and bamboo lands, respectively (Table 5). The results presented in variance show that there was significant difference (P<0.05) in available phosphorus among land use/land covers. Based on the rating set by IFA (1992) and showed in Table 5, soils of the watershed was very low status in the available P content (Table 6). The observed reason in the watershed could be due to leaching and nature of erosion and amount of soil minerals, soil acidity and management practices. Due to this result Morgan (2005), who suggested that when available phosphorus in the soil is less than 7 mg/kg, it is should be supplemented with phosphorus fertilizers. Accordingly this, the current Kamshty watershed area soils are mainly deficient in phosphorus and suggesting that application of phosphorus fertilizers.

Available Potassium (Av. K)

The amount of available potassium in the soils of the study area ranged between 82.14 mg/kg soil (grazing land) and 244.48 mg/kg soil (enset land), respectively (Table 5). The result presented in analysis of variance show that there was significant difference (P<0.05) in available K among the watershed land use/land covers. As seen in Table 5 and 6, the result of available potassium was medium in the upland soils, whereas in the midland and lowland of the watershed was high. The reasons for this variation in the watershed may be variation in amount of clay, parent materials, leaching, and soil management practices.

ISSN: 2455-6939

Volume:04, Issue:04 "July-August 2018"

Cation Exchange Capacity (CEC)

The CEC was different in the watershed that ranged from high value of 34.82 cmol $_{(+)}$/kg soil) to very high value of 43.72 cmol $_{(+)}$/kg soil) (Table 5). Analysis of variance showed that the CEC of the soils in the study area was insignificantly different ($P<0.05$) among the various land use/land covers soil within the watershed. According to Hazelton and Murphy (2007) that the CEC of the watershed was very high range (Table 6). The reason for this is could be due to high amount of clay soil and changes in land use. High CEC may indicate high levels of clay, which has low permeability and internal drainage due to high soil compaction. Thus, soil CEC is expected to increase through management of the soil OM content.

Table 6: Ratings of physical and chemical soil properties in the soil

	Nutrient Ratings				
Soil property	Very high	High	Medium	Low	Very low
Total N (%) [c]	> 1	0.5-1	0.2-0.5	0.1-0.2	< 0.1
Av. P (mg/kg) [d]	>22	13-22	6.5-13	3-6.5	<3
Av. K(mg/kg) [d]	>300	175-300	100-175	50-100	<50
CEC [f]	> 40	25- 40	12 – 25	6 – 12	< 6

Sources: [c] Landon (1991), [d]IFA (1992), [f]Hazelton & Murphy (2007)

4.2 Quantification of Mean Annual Soil Erosion Risk Analysis

The final result of Universal Soil Loss Equation (USLE) was mean annual soil loss risk rate application model which was applied by using raster calculator method of ArcGIS spatial analysis function of cell by cell with 30 m cell size. Based on this, the erosion hazard map of the watershed has been prepared and analyzed. As a result of this, in the study area the annual soil erosion rates ranged from 0-260.45 t ha^{-1}year^{-1} (**Fig. 7**). Therefore, the extended annual soil loss quantified for the entire watershed was 260.45 t ha^{-1}year^{-1}, which make a total soil loss of 49,192.95 tons per year.

In the study area, the quantified mean annual soil loss rate of the entire watershed soil loss was 26.04 t ha^{-1} year^{-1}, which is not comparable to the mean soil loss rate studied by Morgan (2005) for the acceptable soil loss from less than 11 t ha^{-1} year^{-1} as tolerable for tropical soils. Accordingly this, the current mean annual soil loss rate in the study area was not classified under soil loss tolerance limits recommended by the Morgan's finding. Therefore, the present value indicates that there is still a need to do more for designing appropriate land management measures that slow down the amount of soil loss in the study area, otherwise the increasing of erosion severity rate cannot be irreversible.

4.3 Soil Erosion Risk Areas Map

In this study, USLE model was integrated with Remote Sensing and GIS techniques to conduct soil erosion risk areas map of kamshty watershed by determining five parameters such as soil erosivity, soil erodibility, slope length and slope steepness, land use/land cover management, and conservation practices. Thus, the soil loss amount, severity and extents were varied for the different areas of the watershed.

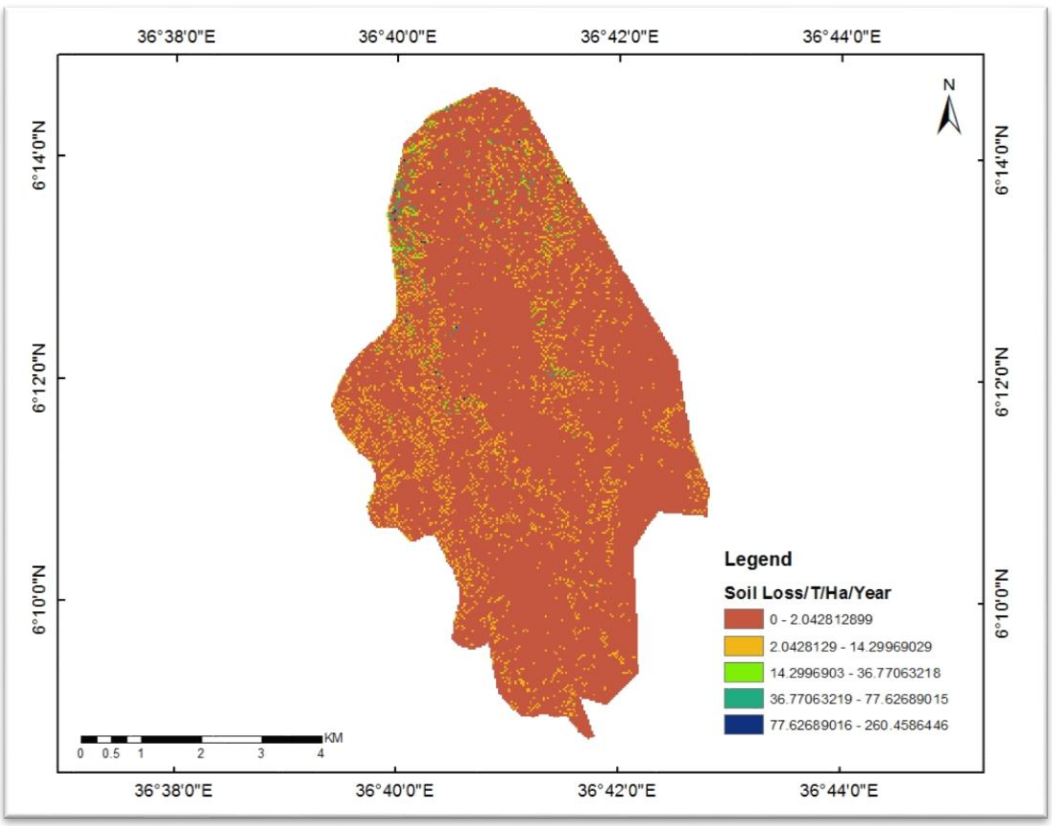

Fig 7: Soil erosion risk areas map of Kamshty watershed

In order to make the presentation simple, the quantified soil loss rate and the map of the study area classified in to five categories based on the severity and risks of soil erosion (**Table 7 and Fig.7**).

ISSN: 2455-6939

Volume:04, Issue:04 "July-August 2018"

Table 7: Annual soil loss rates and severity classes with their conservation priority in the Kamshty watershed

Soil loss (t ha $^{-1}$ y $^{-1}$)	Severity class	Priority classes	Area (ha)	Percent of total area	Annual soil loss (tone)	Percent of total annual soil loss
0-2.04	Low	V	1463	37.3	1492.26	3.04
2.04-14.29	Moderate	IV	1086	27.8	6651.75	13.52
14.29-36.77	High	III	504	12.9	5664.96	11.51
36.77-77.62	Very high	II	609	17.3	12438.82	25.28
77.62-260.45	Severe	I	251	4.7	22945.16	46.65
			3913	100	49,192.95	100

In terms of exposure to the risk of erosion, about 37.3 % of the watershed is characterized low soil erosion rate, which is 0-2.04 t ha^{-1} year^{-1} and such areas can be considered as low risk areas (**Table 7 and Fig.7**), which are dominantly found in southern and central-east part of watershed. This might be due to the contribution of different land use/land covers such as enset/banana, bamboo and eucalyptus tree plantation covers were available in most parts of the study area. On the other hand, as seen in **Table 7**, a significant portion of (27.8%) areas of watershed was categorized as moderate risk areas with a rate of 2.04-14.29 t ha^{-1}year^{-1}. As mentioned in the above (**Table 7 and Fig. 7**) the watershed of the total area (65.1%) is experiencing ‘low’ to ‘moderate’ soil losses with the total area of 2,549 ha, which is significantly covered (16.6%) of the total soil loss with a total annual soil loss of 8,144.01 tones per year, which is found in southern and central-east and west parts of the watershed.

As illustrated in **Table 7 and Fig.7**, high to sever erosion risk areas (14.29-260.45 t ha^{-1}y^{-1}) was found in northern, central, and central-west parts of the watershed. These areas shared a significant amount of total soil loss in the study area accounted (83.4%) with the total area of 1,363 ha, but these areas contributed (34.9%) of the total area in the watershed with a total annual soil loss of 41,048.94 tones per year. In this regard, these areas are more severely degrading than others. This may be related to the hilly nature, intensively cultivated lands and appearance of escarpment in the watershed. Even though, the real reason for this high contribution soli loss in the area is due to improper farming practices, unsustainable use of

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Volume:04, Issue:04 "July-August 2018"

natural resources, and lack of soil conservation and vegetation cover. Hence, these high to sever areas are the critical areas that require urgent soil and water conservation measures.

CONCLUSION

Based on field observation, laboratory analysis of soil samples and the application of USLE with Remote Sensing and Geographic Information System in quantification of soil erosion risk of the watershed concludes that the soil erosion problem is a major environmental threat to the sustainability and productive capacity of agriculture in kamshty watershed area. The main reason for this sever problem is poor vegetation cover and inappropriate farming practices could contributed to the high rate of soil erosion. Hence, community based soil and water conservation measures should be practiced in their cultivated lands by applying different soil protective techniques at the watershed based on the given priority classes.

For long-term sustainability of soil and other natural resources in the watershed areas, the conservation of existing vegetation cover and also replanting of non-harm or environmental friendly vegetation cover should be practiced except eucalyptus plantation which is harming the agricultural lands of the surrounding area by changing the hydrological and nutrient status, and this is therefore affecting the land productivity of the area. The soil fertility management problem in the study area on agricultural lands can be done through the use of adequate integrated soil fertility amendment inputs and minimizing organic nutrient losses by applying chemical fertilizers, and organic inputs such as manure, crop residues, crop rotation, agroforestry, and domestic waste to the agricultural land. Hence, practitioners should advocate to the farmers to apply these amendments. Thus, due to low results of the soil nutrient status of the study area, future studies, attention should be given to quantify nutrient inflows and outflows at farm scale and its implications on sustainability of nutrient management, and in addition to this also attention should be given to the implications of land use/land cover dynamics for natural resource degradation.

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