

Costs of Nutrient Losses in Priceless Soils Eroded From the Highlands of Northwestern Ethiopia

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Abstract

A study was conducted in 2011 to estimate soil and nutrient losses caused by water erosion and predict nutrient replacement costs on different land use types and slope classes at Harfeta watershed, Northwestern Ethiopia. The revised soil loss equation (RUSLE) was used to estimate the soil loss from the different land uses and slope classes in watershed. Moreover, nutrient loss from similar units was calculated by multiplying the in situ nutrient concentration of soil samples by the estimated soil loss using RUSLE. The replacement costs of nutrient losses were calculated by multiplying the nutrient loss with the price of available nutrients in urea and diammonium phosphate. The estimate of the RUSLE indicated that the average soil losses in the study watershed were 119 tons $\text{ha}^{-1} \text{year}^{-1}$ for non-conserved crop land, 23 tons for conserved farmlands, 23 tons for forest and shrub lands, 19 tons for grazing lands, and 6 tons for plantation forest. The mean soil loss for lower slope classes ($<15\%$), middle slope classes ($15-30\%$) and upper slope classes ($>30\%$) were 30.11, 48.09 and 57.22 tons $\text{ha}^{-1} \text{year}^{-1}$, respectively. The highest losses of total nitrogen ($154.7 \text{ kg ha}^{-1} \text{year}^{-1}$), available phosphorus ($1.84 \text{ kg ha}^{-1} \text{year}^{-1}$), and organic matter ($1677.9 \text{ kg ha}^{-1} \text{year}^{-1}$) were obtained from non-conserved cropland. Conversely, the lowest values of the same parameters were registered from the land covered with plantation forest. Comparing slope classes for non conserved cropland, organic matter and nutrient losses were higher in upper slope classes followed by middle and lower ones. The replacement cost of available N and available P for non-conserved cropland, conserved cropland, forest/shrub lands, grazing lands and plantations were 121.22, 36.41, 27.09, 32.22 and 13.10 Birr $\text{ha}^{-1} \text{year}^{-1}$, respectively (1USD = 19 Birr); and the weighted mean replacement cost in the watershed was estimated to be 98.1 Birr $\text{ha}^{-1} \text{year}^{-1}$ which is about 20% of the cost of fertilizer applied per individual farmers in the watershed. From the study it was possible to conclude that conversion of forest lands and plantation forests to cropland causes serious soil and nutrient losses. Construction of conservation structures on cropland, however, will reduce soil and nutrient losses. To halt soil and nutrient loss and ensure sustainable land management and agricultural development in the Harfeta watershed and similar watersheds, policy and development interventions including increasing awareness of farmers on soil and nutrient losses, enforcing land use policies and expanding bio-physical soil conservation practices are required.

Keywords: slope class, water erosion, soil loss, nutrient loss, nutrient replacement cost, harfeta watershed

1. Introduction

Ethiopia is endowed with wealth of biophysical resources including rich biodiversity, relatively fertile soils, and huge fresh water resources. This rich natural resource base has been serving as the foundation for agricultural development and meeting the basic needs of millions of rural people in the country (Gete et al., 2006). Agriculture accounts for about 45.5% of GDP, 85% of the employment opportunity and 94% of Ethiopia's export (NBE, 2002). However, the productivity of that economy is being seriously eroded by unsustainable land management practices in crop and animal feed production systems (Berry, 2003). The Ethiopian rural environment has suffered an accelerating de-vegetation leading to diminishing soil fertility, enhanced soil erosion, increased severity of the impact of drought, and a further reduction in the ability to produce food and other biological resources (Aster, 2004).

Soils are the main terrestrial reservoir for organic matter and nutrients like nitrogen and phosphorus. Depletion of soil fertility leads to declining crop yields and a rise in the number of food insecure people (Bojo & Cassells, 1995; Woldeyesus & Chilot, 2002). Soil and nutrient loss has been identified as an important factor controlling productivity (Seastedt et al., 1991). Soil nutrient mining is caused due to net nutrient extraction by crops and loss along with eroded soil in the highlands of Ethiopia. EFAP (1994) estimated that about 1.9 to 3.5 billion tons of fertile topsoil are being washed away each year from Ethiopian highlands mainly as the ultimate result of deforestation.

Stoorvogel and Smaling (1990) reported that estimate of nutrient losses from soils of the highlands of Ethiopia is in excess of 80 kg ha⁻¹ of N, P₂O₅ and K₂O from cultivated lands whereas addition of nutrient through fertilizer applications amounts to only 10 kg/ha (i.e. 12% of the loss). Due to this reason, land degradation greatly affects agricultural productivity (Demel Teketay, 2005). Chilot and Hassan (2010) also reported that in 1990 alone, decrease of soil depth caused by erosion was estimated to be 3.5 mm to 8.0 mm resulting in a grain production loss of 57,000 to 128,000 tons. Taking in to account the per-capita consumption of cereals in sub-Saharan Africa range from 39.7 - 134.1 kg per annum (FAO, 1987), the grain production lost due to land degradation in 1990 would have been sufficient to feed more than four million people.

To increase yield of crops, many farmers in the highlands of Northwestern Ethiopia use inorganic fertilizers. Fertilizer (DAP and Urea) imports have shown an increasing trend for the past four decades. In the years between 1996 and 2011, imported volumes increased from 100,000 tons to over 500,000 tons (Addis-Fortune, 2011). Even though in recent years the use of fertilizer has increased in Ethiopia, there is evidence that most farmers are not adequately compensating for the loss of soil nutrients caused by erosion and crop uptake (Mulat, 1996). Evidences are, however, very few to generate development and policy recommendations. Hence, generating data on the level of soil and nutrient losses from different land uses and slope classes helps to solidify facts that will be used to advise policy makers and development practitioners on the intervention mechanisms. However, limited information is available in northwestern Ethiopia. This particular study was, therefore, conducted in Harfeta watershed, Libokemkem woreda, South Gondar Zone of northwestern Ethiopia. Hence, the major objective of this research was to estimate soil, nutrient and organic matter losses and calculate the replacement costs of major nutrients lost by erosion from the watershed.

2. Materials and Methods

2.1 Description of the Study Area

Harfeta watershed is found near Yifag town in Libokemkem District, South Gondar Zone, Amhara National Regional State (ANRS) in northwestern Ethiopia (Figure 1). The watershed falls within an altitudinal range of 1880 and 2100 m.a.s.l. The ten years mean maximum and minimum temperatures were 27.9°C and 11.1°C, respectively (Libokemkem Woreda Office of Agriculture, 2009). Similarly, the mean annual total rainfall range between 900 and 1400 mm with uni-modal distribution that occurs from June to September (Begashaw, 2005). The topography of the area varies from slightly flat land to sloppy land with a slope ranging from 5 to 60%. The watershed encompasses different land uses such as cropland (215 ha), forest/shrub land (23 ha), plantation forest (5.5 ha), grazing lands (8.9 ha) and rock outcrops (1.3 ha). The cultivated land covers 87% of the watershed and the majority of it is not treated with physical conservation measures.

2.2 Soil Samples Collection and Analysis

After a reconnaissance survey guided by the topo-map of the study area was conducted, 65 soil samples from five land use types including non-conserved cropland, conserved farmlands, forest, grazing land and plantation forest were collected from a transect at a grid of every 100 m along the slope and every 250 m across the slope from 15 cm soil depth using system outlined in Yao et al. (2010). GPS points were recorded to locate the sampling locations (Figure 2). The collected soils were analyzed for organic matter (OM) following Walkley and Black procedures (Nelson & Sommers, 1982); total N (TN) using Kjeldhal method (Bremner & Mulvaney, 1982); and available P (AP) was estimated using the Olsen method (Olsen & Sommers, 1982). Soil pH was determined in 1: 2.5 soil water ratio. The mean nutrient availability indices from each land use type and slope classes were used to estimate the nutrient loss with eroded soil from the watershed.

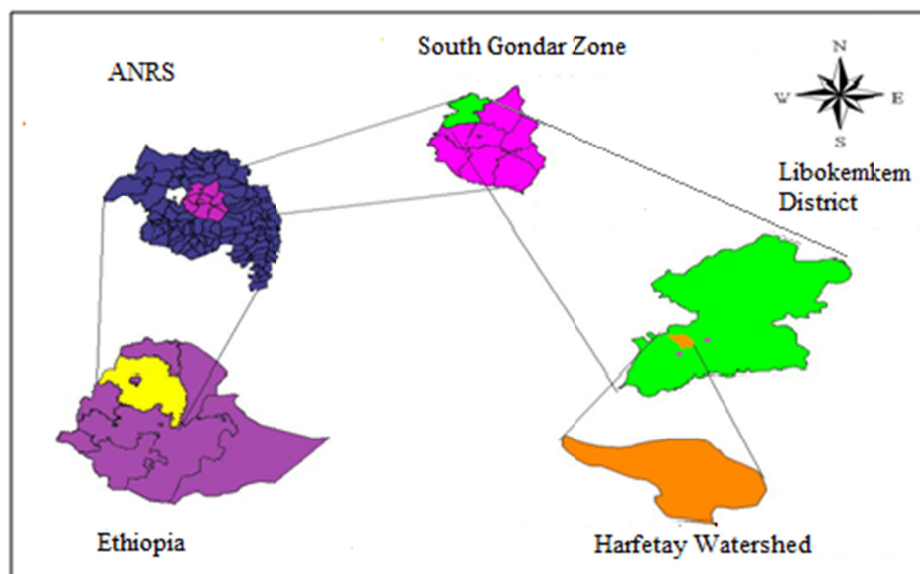


Figure 1. Location of the study area

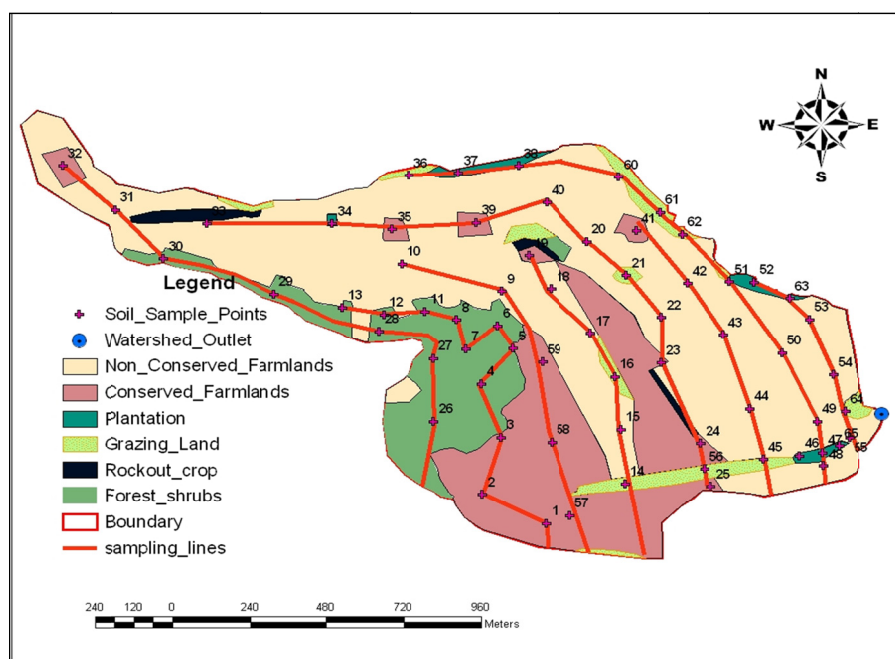


Figure 2. Soil sampling lines, soil sample points and land use types

2.3 Estimation of Soil Loss

To estimate the soil loss in the watershed, land use types were delineated into appropriate size using natural barriers. Annual soil losses in the form of runoff from different land uses and slope classes of the watershed were estimated using the Revised Universal Soil Loss Equation (RUSLE) developed by Wischmeier and Smith (1978) and calibrated for Ethiopia by Hurni (1985) which is

$$A = R * K * L * S * C * P \quad (1)$$

Where A is the estimated soil loss ($t\ ha^{-1}\ yr^{-1}$); R is the rainfall erosivity factor; K is the soil erodibility factor; L is the slope length factor; S is the slope gradient factor; C is the land cover factor and P is the management practice factor.

The erosivity factor (R) was extrapolated from a tabular value developed by Wischmeier and Smith (1978) adapted by Hurni (1985) for Ethiopian conditions based on the long term mean annual rainfall (P) as $R = -8.12 + [0.562 \times P]$. The “R” value for the average rainfall of the watershed (1320.5 mm) was found to be 734. To determine “K”, a systematic observation on soil color of watershed was carried out, based on the approach described in Hurni (1985). Hence, “K” values for black, brown, red and yellow soils are 0.15, 0.20, 0.25 and 0.30, respectively. The tabular values for the slope length factor (L) and slope gradient factor (S) were determined from the distance between two points along the slope and slope gradients in percent. The land cover (C) represents the ratio of soil loss under a given land cover/land use to that of the bare soil (Morgan, 2005) or continuous fallow (Wischmeier & Smith, 1978). Assessment of the type of land use-cover was made separately for each land unit and the corresponding land cover factor was obtained from Hurni (1985). The major crop covers found in the watershed were cereals and pulses. As a result 0.15 was used as crop factor for agricultural lands. Moreover, the land cover factor for forests and bush lands were taken as 0.01, for plantations as 0.01 and for grazing lands as 0.05.

The management practice factor (P) gives the ratio between the soil loss expected for a certain soil conservation practice to that with up-and down-slope ploughing (Wischmeier & Smith, 1978). Specific cultivation practices affect erosion by modifying the flow pattern and direction of runoff and by reducing the amount of runoff (Renard & Foster, 1983). In areas where there is terracing, runoff speed could be reduced with increased infiltration, ultimately resulting in lower soil loss and sediment delivery. Values for this factor were assigned considering local management practices and based on values suggested in Hurni (1985). Hence “P” values are 1.0 for ploughing up and down, 0.9 for ploughing on contour, 0.80 for strip cropping, 40% stone cover, intercropping and grass strips; 0.70 for dense intercropping; 0.60 for applied mulch, and 0.50 for 80% stone cover.

2.4 Estimation of Nutrient Loss and Replacement Cost

Nutrient concentrations in soil are often expressed in terms of kg ha^{-1} for a given depth within the soil profile. To determine the nutrient loss, the estimated soil amount being lost and nutrient concentration must be known or have to be estimated (Marx et al., 1999). Since the watershed does not have gauging station and RUSLE is estimating soil loss without taking actual measurements, nutrient and organic matter losses were determined by multiplying the *in-situ* nutrient and organic matter contents of soil in different land use systems and three slope classes by the amount of soil loss from each land use types and slope classes estimated by RUSLE.

Since the soil eroded by water largely contains finer particles and top soil compared to soils that remain *in situ*, the eroded soil is expected to have higher amount of nutrients. Therefore, the estimate in this procedure is expected to underestimate the nutrient losses. However, this approach still serves the purpose for estimating nutrient losses that can serve as an input to policy and development recommendations. The replacement costs of available nitrogen and phosphorus lost from the watershed along the soil eroded by water from different land use types (LUTs) and slope classes were estimated by multiplying the estimated amount of nutrient lost with the eroded soil by the cost of equivalent amounts of available nutrients in urea and diammonium phosphate (DAP) fertilizers.

The process of 1kg of N and P were calculated using the following formulas:

$$\text{Price of 1 kg available N} = \text{total price of applied N fertilizer} / \text{Nutrient content of fertilizer applied} \quad (2)$$

$$\text{Price of 1 kg available P} = \frac{\text{the price of 100 kg of DAP} \times (\text{price of 1kg of N} \times \text{N content in DAP})}{\text{AP content in DAP}} \quad (3)$$

2.5 Statistical Analysis

One way analysis of variance (ANOVA) was used to detect differences among the land use types and slope classes. When ANOVA test was found to be statistically significant ($p \leq 0.05$), further analysis of mean separation was carried using Duncan's Multiple Range Test (DMRT) using Duncan's multiple range test (DMRT) available in SPSS version 16 software.

3. Results and Discussion

3.1 Determination of *in Situ* Soil Physico-Chemical Properties

Measurements made to analyze the nutrient contents indicated that there were significant differences ($p < 0.05$) in total nitrogen, available nitrogen, available phosphorus, organic matter, bulk density and pH among the various land use types and slope classes (Table 12). Higher level of TN, and AP were registered from plantation forests followed by grazing lands and forest/shrub lands and the lowest levels were found in non-conserved croplands. Based on classifications of Landon (1991), the total N contents can be categorized as low in non conserved and conserved croplands and medium in the other land uses. The organic matter contents are also very low in non conserved as well as conserved croplands; and low in other land uses. However, the available P contents can be

grouped as medium in forest and shrub lands and high in other land uses. The highest bulk density was registered from non-conserved croplands where as the lowest was found from forest and shrub lands. Soil pH was significant difference ($p < 0.05$) among different land use types. The presence of low pH value in forest lands and shrub lands could be due to high OM in forest and shrub lands. Its decomposition leads to the formation of organic acids and leaching of basic cations which lowers the pH value.

Table 1. Chemical soil characteristics for land use types and slope classes

Land use Types	TN (%) [*]	OM (%) [*]	AP (mg kg ⁻¹) [*]	BD (gm cm ⁻³) [*]	pH (1:2.5 H ₂ O) [*]
Non conserved cropland	0.13 ^b	1.41 ^b	15.43 ^{bc}	1.34 ^a	6.4 ^a
Conserved cropland	0.15 ^b	1.47 ^b	21.63 ^b	1.32 ^a	6.1 ^{ab}
Forest and Shrub lands	0.21 ^a	2.80 ^a	9.46 ^c	1.08 ^b	5.9 ^b
Grazing lands	0.22 ^a	2.51 ^a	20.86 ^b	1.13 ^b	6.2 ^{ab}
Plantation forest	0.24 ^a	2.61 ^a	29.86 ^a	1.29 ^a	6.3 ^{ab}
Slope classes in non-conserved cropland					
Lower slope class (<15%)	0.17 ^a	1.89 ^a	20.88 ^a	1.30 ^a	6.4 ^a
Middle slope class (15-30%)	0.17 ^a	2.06 ^a	18.16 ^{ab}	1.22 ^{ab}	5.9 ^a
Upper slope class (>30%)	0.22 ^a	2.47 ^a	11.48 ^b	1.10 ^b	5.8 ^b

TN: total N; OM: organic matter; AP: available phosphorus; BD: bulk density.

* Means in a column for land use types and slope classes followed by the same letter(s) are not significantly different at $p < 0.05$.

3.2 Soil Loss and Equivalent Nutrient Removal From Different Land Use Types and Slope Classes

Soil erosion was estimated to be the highest in non-conserved farmlands (about 119 tons ha⁻¹ year⁻¹) because of cultivation of rolling mountains and poor conservation practices. The major parts of the cultivated farmlands do not have conservation practices although most of the area is found in the steeper slopes naturally prone to soil losses by water erosion. The results obtained in this study were in many of the land uses and slope classes higher than previous reports. Berry (2003) estimated that soil loss by water erosion croplands range from 3.4 to 84.5 tons ha⁻¹ year⁻¹ with a mean of 32 tons ha⁻¹ year⁻¹. In the conserved farmlands, with construction of stone terraces along the contour with a mean distance of 15m, the soil loss was estimated to be 23 tons ha⁻¹ year⁻¹. This soil loss is still double the acceptable limit of soil loss of 12 tons ha⁻¹ year⁻¹ (Ermias et al., 2009) and far exceeds the mean annual rate of soil formation which is 6 tons ha⁻¹ year⁻¹ (Hurni, 1995).

The estimated mean soil loss in forest and shrub lands was 23 tons ha⁻¹ year⁻¹. Even though vegetation cover should reduce erosion, farmers still cut trees and shrubs for fuel wood for household energy source and income generation which reduces the canopy cover exacerbating erosion. As reported in Morgan (2005), it is apparent that living and dead plant biomasses reduce soil erosion by intercepting and dissipating raindrops energy that would detach soil particles from the soil aggregate. Aboveground foliage slows the velocity of water running over the soil decreasing the volume of water and soil lost in surface runoff. Plant roots also physically bind particles, thus stabilizing the soil and increasing its resistance to erosion. Plant roots also enhance water conservation by creating pores in the soil surface that enable water to enter easily into the soil matrix at the expenses of the surface runoff which leads to soil erosion. The uptake of water by plant roots also somehow deplete soil water content and thereby further increases infiltration rates (Bezuayehu et al., 2002). Even though the estimated soil loss in this forest and shrub lands is 19 tons ha⁻¹ year⁻¹, which is less than conserved croplands, grazing lands and non-conserved croplands, this is still by far more than the acceptable limit of soil loss.

The mean annual soil loss estimated from grazing lands was 19 tons ha⁻¹ year⁻¹, which is higher than the acceptable or tolerance limit of soil loss. Mean soil loss in plantations is estimated to be 6 tons ha⁻¹ year⁻¹, which is the lowest soil loss estimated in the watershed. Generally, the mean soil loss was found different ($p < 0.05$) among land use types except for the soil loss in conserved croplands and grazing lands. The weighted mean annual soil loss of the watershed estimated using RUSLE was found to be 84 tons ha⁻¹ year⁻¹.

The mean value of soil loss in higher slope classes was higher than the lower slope classes which was expected since soil erosion increases with an increase of slope steepness associated with an augmentation of the velocity of the runoff. However, there was no difference which could be due to forest and shrub land cover on the upper parts of the watershed and non-conserved croplands on the lower slope classes. Fozi (2000) also reported that slope alone does not significantly influence the amount of soil loss. It is apparent that soil loss is a function of different factors like erosivity, soil erodibility, slope length, slope gradient, land cover and land management practice that are mentioned in the RUSLE (Hurni, 1985).

The losses of TN, AP and OM all were found different ($p < 0.05$) among LUTs. Total N loss was $153.63 \text{ kg ha}^{-1} \text{ year}^{-1}$ from non-conserved croplands, 34.5 from conserved croplands, 48.3 from forest and shrub lands, and 14.4 from grazing lands and plantations (Table 2). The highest loss of TN occurred in non-conserved croplands followed by grazing lands and the least in the plantations which could be directly related to the amount of OM lost from the watershed along with the soil. The AP loss in the watershed was $1.84 \text{ kg ha}^{-1} \text{ year}^{-1}$ from non-conserved croplands, $0.50 \text{ kg ha}^{-1} \text{ year}^{-1}$ from conserved croplands, $0.22 \text{ kg ha}^{-1} \text{ year}^{-1}$ from forest and shrub lands, $0.40 \text{ kg ha}^{-1} \text{ year}^{-1}$ from grazing lands and $0.18 \text{ kg ha}^{-1} \text{ year}^{-1}$ from plantations. The highest loss of AP was found in non-conserved croplands similar to other soil parameters considered followed by conserved croplands and the least occurred in forest and shrub lands. Stoorvogel and Smaling (1990) also reported that Ethiopia had among the highest rates of nutrient depletion in sub-saharan Africa with nitrogen loss reaching 30 kg ha^{-1} and phosphorus loss of $15\text{-}20 \text{ kg ha}^{-1}$. Bojo and Cassells (1995) similarly reported that an estimated gross financial losses due to land degradation reaching $106 \text{ million US\$ year}^{-1}$. The loss of OM in the watershed was $1676.9 \text{ kg ha}^{-1} \text{ year}^{-1}$ from non-conserved croplands, $338.10 \text{ kg ha}^{-1} \text{ year}^{-1}$ from conserved croplands, $644.16 \text{ kg ha}^{-1} \text{ year}^{-1}$ from forest and shrub lands, $476.90 \text{ kg ha}^{-1} \text{ year}^{-1}$ from grazing lands and $156.60 \text{ kg ha}^{-1} \text{ year}^{-1}$ from plantations (Table 2). Similarly, the same parameters were significantly different ($p < 0.05$) among slope classes in the non-conserved croplands (Table 2). More TN and AP losses were observed from the middle slope class ($15\text{-}30\%$) than the upper slope class ($>30\%$) which could be due to the low nitrogen and phosphorus fertilizers additions in these lands which lowered the in situ nutrient content.

Table 2. Soil, nutrient and OM losses from different LUT, management practices and slope classes

Land Use Types	Soil Loss ($\text{tones ha}^{-1} \text{ year}^{-1}$)	($\text{kg ha}^{-1} \text{ year}^{-1}$)*		
		TN	AP	OM
Non conserved croplands	119.0a	154.7 ^a	1.84 ^a	1677.9 ^a
Conserved croplands	23.0 ^b	34.5 ^{bc}	0.50 ^b	338.10 ^{bc}
Forest and shrub lands	23.0 ^b	48.3 ^b	0.22 ^c	644.16 ^b
Grazing lands	19.0 ^c	41.8 ^b	0.40 ^b	476.90 ^b
Plantation	6.0 ^d	14.4 ^c	0.18 ^c	156.60 ^c
Slope classes non- conserved croplands				
Lower slope class ($<15\%$)	51.19 ^c	69.40 ^b	0.63 ^b	769.08 ^c
Middle slope class ($15\text{-}30\%$)	81.75 ^b	80.79 ^a	0.87 ^a	990.65 ^b
Upper slope class ($>30\%$)	125.88 ^a	53.85 ^c	0.66 ^b	1413.33 ^a

* Means in a column for land use types and slope classes followed by the same letter are not different at $p < 0.05$.

3.3 Nutrient Replacement Costs in Different Land Use Types and Slope Classes

It is apparent that organic matter, micro and macro nutrients are getting lost with soil lost in erosion. However, it is easier to quantify the replacement costs of most of the nutrients but not that of organic matter since its costs are not known. The fertilizer types used in the study area are urea and DAP which are the only fertilizers imported and distributed in the country. The price of fertilizers was 885 and 1172 Birr for 100 kg of urea and DAP, respectively in 2011 (1US\$ = 19.00 Birr). The average amount of fertilizers used by individual farmers in the watershed is 25 kg of urea and 25 kg of DAP per household. It is found that farmers use these fertilizers for major crops like maize (*Zea mays*), wheat (*Triticum aestivum*) and teff (*Eragrostis tef*). The cost of 1 kg of available nitrogen in urea (46% N) and DAP (18%N) was 19.24 Birr and the cost of 1 kg of AP in DAP was 41.29 Birr. DAP contains 18% nitrogen and 20% available phosphorus (AP) (Table 3).

Table 3. Costs of fertilizers applied and prices of nitrogen and available phosphorous in the watershed

Fertilizer types	Types of Nutrient	Grade	Nutrient Content (%)	Mean fertilizer use by farmers (kg)	Price of Fertilizer applied (Birr kg ⁻¹)	Cost of fertilizers applied (Birr)	Nutrient content of fertilizers applied (kg)	Price of nutrients (Birr kg ⁻¹)
urea	AN	46-0-0	46	25	8.85	221.25	11.5	19.24
DAP	AN & AP	18-46-0	18 AN & 20AP	25	11.72	293.00	4 N & 5P	19.24 for AN & 41.29 for AP

The mean replacement costs of N and AP were found significantly different ($p < 0.05$) among LUTs with the highest replacement cost in the non-conserved croplands and the lowest in plantations (Table 4). The weighted mean replacement cost of AN and AP nutrients lost in terms of fertilizer cost from different land use types was estimated to be 98.1 Birr (Table 4) which was higher than reported by Nigussie Haregeweyn et al. (2007) for Tigray Region. The value of nutrient replacement cost from non conserved croplands was the highest loss compared to other land uses which is 121.23 Birr ha⁻¹ year⁻¹. The second largest replacement cost estimated to occur was in conserved croplands with 36.41 Birr ha⁻¹ year⁻¹ followed by grazing lands with 32.22 Birr ha⁻¹ year⁻¹. Forest and shrub lands and plantations had the lowest replacement cost of nutrients estimated with 27.09 and 13.10 Birr, respectively.

The weighted mean replacement costs of AN and AP are 34.01 and 42.31 Birr ha⁻¹ year⁻¹, respectively. The weighted mean AN and AP nutrient loss from the watershed (98.1 Birr ha⁻¹ year⁻¹) is equivalent to 20% of mean cost paid for fertilizer by individual farmers in the watershed. But the replacement costs of nutrients lost from non-conserved croplands comprises 24% of fertilizer added by individual farmers. If the weighted means loss replacement cost is extrapolated to the high lands of Amhara region (161,828.4 km²) (Begashaw Molla, 2005) and the highlands of Ethiopia (4.48 x 10⁵ km²) (Nigussie et al., 2007) will be 1.59 and 4.39 billion Birr, respectively. The inclusion of TN and OM and other nutrients losses as well as the deterioration in soil physical properties raises the cost to a much higher level (Nigussie et al., 2007). Bojo and Cassells (1995) also reported estimated gross financial losses at 106 million US\$ year⁻¹ due to land degradation. The mean replacement cost of AN and AP increases when we go from lower slope class to middle and upper slope classes.

Table 4. Mean Nutrient loss and replacement costs of AN and AP

LUT	AN		AP		Total nutrient replacement cost (Birr ha ⁻¹ year ⁻¹)
	kg ha ⁻¹ year ⁻¹	Birr ha ⁻¹ year ⁻¹	kg ha ⁻¹ year ⁻¹	Birr ha ⁻¹ year ⁻¹	
Non conserved croplands	2.36 ^a	45.40 ^a	1.84 ^a	75.82 ^a	121.22 ^a
Conserved croplands	0.82 ^b	15.87 ^b	0.50 ^b	20.54 ^b	36.41 ^b
Forest and shrub lands	0.94 ^b	18.10 ^b	0.22 ^c	8.98 ^c	27.09 ^b
Grazing lands	0.82 ^b	15.85 ^b	0.40 ^b	6.36 ^c	32.22 ^b
Plantations	0.30 ^c	5.70 ^c	0.18 ^c	7.40 ^c	13.10 ^c
Weighted mean replacement cost		34.01		42.31	98.1
Slope class in non- conserved croplands					
Lower slope class (<15%)	0.88 ^b	16.93 ^b	0.63 ^a	25.95 ^b	42.39 ^c
Middle slope class (15-30%)	2.36 ^a	45.33 ^a	0.87 ^a	36.06 ^a	81.39 ^a
Upper slope class (>30%)	2.16 ^a	41.52 ^a	0.66 ^a	27.12 ^b	68.64 ^b

* Means in a column for land use types or slope classes followed by the same letter are not different at $p < 0.05$.

4. Conclusions and Recommendations

The study showed that the mean soil loss together with the nutrients and organic matter in it due to water erosion is very high on farmlands devoid of vegetation. Continuous soil losses of top soil leads to the occurrence of unproductive subsoil and rock outcrops which depress yields and increase food insecurity for the local community.

Furthermore, new forest and shrub lands found on the steep slopes will be cleared for their livelihood. Therefore, there is urgent need of strengthening soil conservation practices in existing farmlands to prevent expansion of crop production to forest lands and steep slopes which otherwise aggravates soil loss rate and flood hazards. In fact, extensive work on awareness of the paramount importance of soils conservation practices in slope lands of Northeastern Ethiopia should be given high priority. Moreover, enforcement of the land use policy of Amhara National Regional State is critically required for sustainable natural resources management.

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