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Research Article

Estimating Soil Loss Using Universal Soil Loss Equation (USLE) for Soil Conservation planning at Medego Watershed, Northern Ethiopia

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ABSTRACT: Water erosion is a major part of land degradation that affects the physical and chemical properties of soils and resulting in on-site nutrient loss and off-site sedimentation of water resources in arid and semi-arid areas of Ethiopia. The heavy reliance of some 85 percent of Ethiopia's growing population on an exploitative kind of subsistence agriculture is a major reason behind the current state of land and soil degradation. Tackling on-site effects of soil erosion requires understanding of the rates of soil loss as well as identification of the major controlling factors that enhance or retard these processes. Therefore, the objective of this study was to predict the amount of soil loss in different landforms and land uses using USLE which is modified and adapted to Ethiopian conditions, at Medego watershed, northern Ethiopia. This study was conducted after massive SWC practices have been implemented in the past 15-year in the study watershed. Primary data and secondary data were collected related to the factors that influence soil loss estimated by USLE and for area description. The land surfaces in the watershed is mainly a reflection of past erosion processes as indicated by many researchers. In this study, the lowest soil loss is estimated on flat plains (< 2% slope) about 1.59 tons $ha^{-1} y^{-1}$, which is less than the minimum tolerable soil loss (2 tons $ha^{-1} y^{-1}$) for the country. However, the highest soil loss is from steep slopes (30-50%) which is 35.43 tons $ha^{-1} y^{-1}$, about twice the maximum tolerable soil loss (18 tons $ha^{-1} y^{-1}$). The average soil loss rate at watershed level is 9.63 tons $ha^{-1} y^{-1}$ about half of the maximum tolerable soil loss. The implication is the contribution of the implemented SWC measures in decreasing the rate of soil erosion is encourageable as compared to the results related to high soil loss estimated in the past studies i.e., before massive SWC implementation. However, the present value indicates still a need for wise SWC planning that decreases the amount of soil loss in the watershed at least below the maximum tolerable soil loss rate of the country. Therefore, to maximize the available resources in targeting the effect of water erosion on soil loss, those landforms and land uses having large rate of erosion should be given first priority during the introduction of intensive and well designed SWC interventions at Medego watershed, northern Ethiopia. [Journal of American Science 2009: 5(1), 58-69] (ISSN: 1545-1003)

Key words: Medego watershed, northern Ethiopia, soil loss, tolerable soil loss.
Abbreviations: SWC- soil and water conservation, USLE-Universal Soil Loss Equation.

1. INTRODUCTION

Growing degradation and loss of soil means that the expanding population in many parts of the world is pushing this resource to its frontier. In its absence, the biospheric environment of humans would collapse with devastating effects on humanity. Judson (1965) was one of the first geologists to assess the world soil erosion. He estimated that the amount of river-borne soil carried into the oceans had increased from 9.9 billion tons a year before the introduction of agriculture, grazing and related activities, to the present rate of 26.5 billion tons a year. Hydrologists estimated that one-fourth of the soil lost through erosion in a watershed actually makes it to the ocean as sediment (FAO/UNEP, 1978). The remaining three-fourths are deposited on foothill slopes, in reservoirs, in river plains and other low-lying areas or in the river-bed itself, which often causes channel shifts. In an overview of global erosion and sedimentation, Pimental (1995) stated that more than 50% of the world's pastureland and about 80% of agricultural land suffer from significant erosion.

The causes of land degradation are complex and have diverse nature and dimensions, depending on peculiarities of different countries,

influenced as it is by a combination of natural and socio-economic-cultural factors. In Ethiopia, the heavy reliance of some 85 percent of Ethiopia's growing population on an exploitative kind of subsistence agriculture is a major reason behind the current state of land degradation. Moreover, land degradation is a long-term process in which the effect and steady expansion is hardly noticed until it manifests itself with disastrous drought and famine. Most studies indicate that sheet and rill erosion by water and burning of dung and crop residue are the major components of land degradation that affects on-site land productivity (Hurni, 1993; Zeleke et al., 2001).

Water erosion is a major part of land degradation that affects the physical and chemical properties of soils and resulting in on-site nutrient loss and off-site sedimentation of water resources in arid and semi-arid areas like Ethiopia (Boardman, 1998; Lal, 1999; Bartsch et al., 2002; Emrah et al., 2007). The off-site effects of erosion such as reservoir sedimentation and water resources pollution are usually more costly and severe than the on-site effects on land resources (Phillips, 1989). Therefore, proper management of on-site effect of soil erosion could reduce the risks and negative impacts of down stream water resources due to water erosion. Tackling the on-site effects of soil erosion requires an understanding of the rates of erosion processes as well as identification of the major controlling factors that enhance or retard these processes. The knowledge of "what are the factors and where" may help to distinguish the potential causes and the associated reasons behind the respective causes even though this may not be enough to design site-specific management, as the factors playing a major role in erosion may be widely distributed within watersheds (Ferro et al., 1998; Mirco et al., 2003).

Soil erosion by water and its associated effects are recognized to be severe threats to the national economy of Ethiopia (Hurni, 1993; Sutcliffe, 1993, Tamene, 2005). Since more than 85% of the country's population depends on agriculture for living, physical soil and nutrient losses lead to food insecurity. Hurni (1990, 1993) estimates that soil loss due to erosion in Ethiopia amounts to 1493 million tons per year, of which about 42 tons ha^{-1} y^{-1} is estimated to have come from cultivated fields. This is far greater than the tolerable soil loss as well as the annual rate of soil formation in the country. According to an estimate by FAO (1986), some 50% of the highlands of Ethiopia are already 'significantly eroded,' and erosion causes a decline in land productivity at the rate of 2.2% per year. The study also predicted that by the year 2010, erosion could reduce per capita incomes of the highland population by 30%. Hence, soil and water conservation measures have been implemented to alleviate both problems of erosion and drought, which are symptoms of two different extremes of rainfall conditions since the 1980s in the country. However, so far, little or no sufficient documented information has been available on the contribution of the different SWC measures implemented on soil loss reduction since the last 15-years at the study watershed in the semiarid areas of Ethiopia as compared to the tolerable soil loss determined by Hurni (1985) to Ethiopia condition. Such information is vital to take additional measures and soil conservation planning at the watershed and other similar areas in the semiarid areas. Therefore, the purpose of this study was to estimate the amount of soil loss in different landforms and land uses using USLE at Medego watershed, northern Ethiopia.

2. MATERIALS AND METHODS

2.1. Study Area Description

The study was carried out at Medego watershed in the administrative unit of Lalay-maychew district in Tigray region, northern Ethiopia (Figure 1), from August 2007 to July 2008. Its altitude ranges from 2000 to 2720 m above sea level. The study area is bounded by latitudes N14^{o}05.955'and 14°05.937', and longitudes E038^{o}42.352' and 038°42.333'. The total area of the watershed is about 1091.5 ha as delineated using Geographical Positioning System (GPS) during the field study. The study watershed is characterized by different landforms which are ranged from flat plains, undulating plains and rolling land to steep mountains and very steep escarpments. The description of the topography is adopted the slope capability classification made by (Chekun, 2002), and the slope ranges and area coverage of each landform was recorded at field using clinometers and GPS, as it is presented in Table 1. The geological setup of the watershed is originated from volcanic. However, alluvial deposits at flat lands are also found in the watershed. The soil type at the study watershed is quite different along the slope. At steep slopes, coarse earth materials, gravels and boulder are dominated where as at flat

plain, the largest portion of the study area is covered by clay loam soil and the smaller portion laid on clay and sandy soil textures. The main soil types are cambisols on undulating plains and rolling landforms; lithosols on hilly and steep to very steep lands and vertisols are found on the flat plateau plains of the watershed (BoARD, 2007).

The number of households and total population at Medego watershed is 397 and 1537, respectively. The land holding size of most farmers in the study area is less than 1.3 ha. The watershed has uni-modal and erratic rain fall patterns. The rainy season is very short and extends from June to first week of September. The mean annual amount of rain fall ranges from 600 - 700 mm from historical rainfall data. The mean monthly temperature during the growing season ranges from 15 - 20 $^{\circ}$ C (BoARD, 2007). According to the BoARD (2007), the farming system of the study watershed is principally crop oriented. Tef cultivation *(Eragrostic tef)* account for the majority of arable lands and followed by wheat *(Triticum vulgare)* crop. Other crops such as faba bean *(Vicia faba)*, field pea *(Pisum sativum)*, lentil *(Lens culinaris)*, chick pea *(Cicer arietinum)*, flax *(Linum usitatissimum),* barley *(Hordeum vulgare)* and maize *(Zea mays)* are also important crops in the farming system. Irrigation is also widely practiced at Medego watershed. In spite of the fact that the high crop diversification in the watershed, it observed that there is still a room to improve the crop productivity. Livestock rearing is also an integral part of the farming system, though the number of livestock in the watershed area is reduced from time to time due to animal feed shortage. According to farmers view, cattle are kept mainly for draught power and milking; goat and sheep are kept for live sale; and equines (donkey, mule, horse, camel) for transportation. The study indicated that 83% of the households in the watershed have some livestock. Of these, 75% are cattle (average of 2 cattle per household), 21% are sheep and goats and the rest is covered by poultry and equines.

It was observed that the vegetation in Medego watershed in general is sparse and has been overexploited for long time and at this time consists of shrubs and bushes of little economic value. The available vegetation species in the study area include seraw (*Acacia etbaica*), chea' (*Acacia abyssinica*), acacha (*Acacia decurrence*) and Awhi (*Cordia africana*) on uncultivated land; and momona (*Acacia albida*), tambock (*Croton machostachys*), keyih bahrizaf (*eucalyptus comoldulensis*) and some 'seraw (*Acacia etbaica*) on cultivated and marginalized areas. Leucena (*Leuceana leucacephala*), sesbania (*Sesbania sesban*) and some other grasses are commonly found in the gully of the watershed. Farmers' used such vegetation for the purpose of farm implements, house construction and furniture, fuel wood, soil and water conservation measures and fencing (Table 2). But most farmers have no or little awareness on the function of these tree species for soil and water conservation as compared to the other uses. Hence, awareness creation to farmers in the watershed and other areas should be done in order to the farmers give attention on planting and managing tree species from different perspectives including soil and water conservation, soil fertility improvement.

2.2. Methodology

Primary and secondary data were collected at Medego watershed related to the assessment of SWC measures on soil loss at Medego watershed. Primary data were gathered by topographic transect walk, measuring of input data, informal discussion and observation. The secondary data include climate, demographic and other related data were collected from Bureau of Agriculture and Rural Development (BoARD) at the administrative unit. These data were used to estimate soil loss after tremendous activities of SWC measures have been implemented at Medego watershed, northern Ethiopia. The rapid rural appraisal technique of the topographic transect walk method was employed for its effectiveness in the assessment of the natural resource base and topography of the watershed. In order to obtain as much information as possible, the transect walk was applied in two direction, east to west and south to north. In both directions, the transect walk started at the top edge of the watershed and went all the way across to the other end of the watershed. During the transect walk, observations and estimates of vegetation type and density, and impact of the existing soil and water conservation measures were observed. These were followed by recording land-use types, soil color, soil depth, soil drainage condition, slope gradient and length. The transect walk also provided an opportunity for informal discussions with farmers working on their plots.

Annual soil loss in the form of runoff from different land forms and land uses of the watershed was estimated using the Universal Soil Loss Equation (USLE) (Wischmeier and Smith,

1978) and modified and adapted to Ethiopian conditions by Hurni (1985) and Gebreselassie (1996) as follows.

$$A = R * K * L * S * C * P$$

Where; A = estimated soil loss (t ha^{-1} yr^{-1}), R = Rainfall Erosivity factor, K = Soil Erodibility factor, L = Slope length factor, S = Slope gradient factor, C = Land cover factor, P = Management practice factor

The R-factor is defined as the product of kinetic energy and the maximum 30 minute intensity and shows the erosivity of rainfall events (Wischmeier and Smith, 1978). However, in this study, to determine the value of the R-factor, the average of annual historic rainfall event (10-years) was collected from meteorological station located at 8-Km distance from the watershed. Then the R-value corresponds to the mean annual rainfall of the watershed was found using the R-correlation established in Hurni (1985) to Ethiopia condition. Therefore, the annual R-factor for the average rainfall (650 mm) at the watershed as extrapolated from Hurni (1985) is 357. The soil erodibility (K), slope length (L), slope gradient (S), C, and P-factors of USLE for the entire watershed based on landforms and land use is presented in Table 3.

The K-factor is defined as the rate of soil loss per unit of R-factor on a unit plot (Renard et al., 1997). To determine the value of the K-factor, a systematic observation on soil color of watershed was carried out, based on the approach described in Hurni (1985). This was done by classifying the watershed into similar land uses and land forms (Table 1). For soils having different color in the same land use and landform, the K-factor was taken as their mean value of these colors as it is described on Hurni (1985). As an example, the K-factor for flat plains in Medego watershed is the mean value of the soil color black (0.15) and brown (0.2), which is about 0.18; and the same approach was used in determining the soil color for the other landforms in the watershed (Table 3). SL is the topographic factor expressed as the expected ratio of soil loss per unit area from a field slope to that from a unit plot under otherwise identical conditions. Slope length and slope gradients factors were recorded using meter tape and clinometers, respectively, in the watershed on different landform and land uses. It is taken the weighted value of the slope gradient and slope length range measured at the field for each

landform and land use and so extrapolated based on Hurni (1985) to Ethiopia condition (Table 3 and 4).

The C-factor is defined as the ratio of soil loss from land with specific vegetation to the corresponding soil loss from continuous fallow (Wischmeier and Smith, 1978). Assessment of the type of land use-cover was made separately for each land unit and the corresponding land cover was obtained from Hurni (1985) which was developed to Ethiopia condition. For variations in land cover with specific land unit or landform, the C-factor was obtained using weighted value of the different land cover (Table 3).

The P-factor gives the ratio between the soil loss expected for a certain soil conservation practice to that with up-and down-slope ploughing (Wischmeier and Smith, 1978). Specific cultivation practices affect erosion by modifying the flow pattern and direction of runoff and by reducing the amount of runoff (Renard and 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). Management factors were obtained by assessing the different supporting practices in the study watershed and it was taken the weighted value for similar land forms and land uses types (Table 3). The data related to management practices were collected during the field work. The presence and status of conservation activities were assessed with emphasis on the existing conditions of terraces and protected areas. Most of the areas in the watershed are well-terraced, mainly the upslope parts. However, most of the terraces are broken due to high runoff and/or livestock trampling in many parts of the watershed.

The data were analyzed following the interpolation of the values of USLE in Hurni (1985) and Gebreselassie (1996) to Ethiopia condition. The data was then interpreted qualitatively and using descriptive statistics.

3. RESULTS AND DISCUSSION

3.1. Estimated Soil Loss Using USLE at Medego Watershed, Northern Ethiopia

In spite of the fact that tremendous efforts of SWC have been implemented, their contribution in reducing soil loss due to water erosion demands recent assessment for appropriate future conservation planning. It is understood that heavy rainfall cause severe soil erosion in agricultural fields of the semiarid regions of Ethiopia. Soil erosion in agricultural fields affects not only land productivity but also the water environment in the down stream. Many investigations have been conducted for the development of prediction methods of water-induced soil erosion processes. Among the methods, the empirical Universal Soil Loss Equation (USLE) has been applied broadly for predicting the average annual soil loss from upland fields in Ethiopia (Wischmeier and Smith, 1978; Hurni, 1985) for the reasons described in the discussion part of this paper.

The soil loss estimated using USLE on this study from cultivated land on flat plain land form (< 2% slope) of Medego watershed, northern Ethiopia is the lowest as compared to the other land uses or landforms, which is 1.59 tons $ha^{-1} y^{-1}$ (Table 4). This indicates that soil loss due to rill and inter-rill erosion is almost balanced by deposition within the flat landforms of the watershed. Next to the flat land form, the landforms having lower soil erosion are undulating plains (slope 2-8%) and flat- flood prone areas (< 2% slope) which are 3.13 and 4.87 t $ha^{-1} y^{-1}$, respectively. The highest soil loss at the study watershed was recorded at the landform -steep mountains (slope 30-50%), which is 35.43 tons $ha^{-1} yr^{-1}$. The small soil loss rate of the landforms is related to the factors of the USLE in the watershed (Table 4). Therefore, more attention should be given to slope ranges between 30-50% while SWC measures is planning to implement in the watershed.

The general trends of the finding indicate that soil loss increases as the slope steepness increases in the watershed (Table 4). However, at the landform of very steep mountains (> 50% slope), the annual soil loss is estimated as 7.63 tons ha^{-1}, which is even less than the landforms such as rolling land forms (8-15% slope), hill landforms (15-30% slope) and steep mountains (30-50% slope). This is because these slope ranges are susceptible to daily human interferences such cultivation and grazing as compared to very steep slopes (> 50%) and also slopes having more than 50% in the watershed have land cover of 'Bad Lands Hard' and stone cover which can retain the impact of the kinetic energy of raindrops and at the same time decrease runoff amount. Moreover, there are rock-out crops, which are difficult to detach or transport by raindrops and water erosion on the very steep escarpment of Medego watershed. Landforms more than 50% slopes are protected areas in the watershed. The C-factor represents resistance of the ground surface to the transport of water-soil mixture on the very steep mountains of the watershed includes badlands hard, and bushes and shrubs which dissipate the force of the raindrops. The P-factor stands for erosion inhibition effect, and reflects partly awareness and control measures implemented to minimize soil erosion more than the other landforms by the community (Table 3). It is also noted that the lower slope landforms are susceptible to daily human interferences where as the steepest landforms are protected areas. This proves that the USLE is useful for assessing the adequacy of conservation measures and management practices in agricultural watersheds.

The average annual soil loss estimated by USLE from the entire Medego watershed is 9.63 tons ha^{-1}. If we interpret the annual soil loss as a proxy to watershed erosion, it is possible to see that the magnitude of annual soil loss reported in Table 4 is generally higher than the tolerable soil loss of 2 – 18 tons $ha^{-1} y^{-1}$ estimated for Ethiopia by (Hurni, 1985) except flat landforms of the watershed. The soil loss rate in all the landforms are below the maximum tolerable soil loss for Ethiopia condition, which is 18 tons $ha^{-1} y^{-1}$, except the steep mountains (slope 30-50%) landforms that indicate almost double of the maximum soil tolerance value. In general, the average soil loss in the watershed in about half of the maximum tolerable soil loss and five times the minimum soil loss tolerance value given by Hurni (1985). The implication is that there is a need to integrate a sound management practices so that to decrease the amount of soil loss in Medego watershed, northern Ethiopia below the maximum as well as the minimum soil loss tolerable value for the country.

As compared to the soil loss estimated for Ethiopia as 42 tons $ha^{-1} y^{-1}$ from cultivated fields by Hurni (1990, 1993); 21 tons $ha^{-1} y^{-1}$ (Machado et al. 1995), and 30-80 tons $ha^{-1} y^{-1}$ (Tekeste and Paul, 1989) in Tigray region, northern Ethiopia, the soil loss estimated on this study in 2007/08 is by far the smallest. The results of the present study as compare to past findings indicate that the amount of soil loss from a given unit of land is low. This could be due to the contribution of the

different soil conservation interventions implemented for at least the last decades in the country in general and the study watershed in particular. This related to the fact that SWC intervention increases soil moisture, fertility and decrease slope factor and thereby enhance the availability of vegetation covers. The combined effect of such factors will be decreasing the impact of raindrops, detachment and transporting of soils. This was evidenced by the opinion of the respondents which evaluated as less soil erosion after the soil conservation practices were built at the watershed as compared to before the implementation (data not presented here). Therefore, as noted in the above, the soil loss estimated by different scholars has showed discrepancy for the same environment (semi-arid region of Ethiopia). This implies that there is a need to have site specific (watershed level) information on soil erosion in order to support timely information for decision makers so that to plan the correct soil conservation planning. In doing so, it is categorized the severity of erosion in the study watershed's landforms as follows.

According to Singh and Phadke (2006) classes of soil loss range (*very slight, slight, moderate, severe and very severe*), the mean annual soil loss (9.63 tons ha^{-1}) from Medego watershed, northern Ethiopia is categorized under *slight class* of soil erosion (5 – 9.99 tons ha^{-1} y^{-1}). According to them, the only part of the watershed landforms having *very slight class* of soil loss (0 - 4.99 tons ha^{-1} y^{-1}) are the flat plains, undulating plains and the flat-flood prone areas; and followed by *slight soil loss* (5 – 9.99 tons ha^{-1} y^{-1}) for the very steep escarpment of the watershed; and *moderate soil loss* class (10 – 24.99 tons ha^{-1} y^{-1}) on rolling to hill landforms of the watershed, where as *severe class of soil loss* (25 – 44.99 tons ha^{-1} y^{-1}) was estimated using USLE on slopes 30-50% (Table 4). This doesn't mean that to give less attention to those landforms with very slight to slight soil loss classes in the study watershed but this is to indicate that parts of the watershed landforms that need high priority for SWC implementation using the available existing resource. This is because; it may be worth noting that nature takes 200–400 years to build up 1 cm of top soil (Pimental 1995) but thousands tons of soil are lost in a season from a watershed . He also reported that each millimeters of cultivated soil loss could cost 10 kg of nitrogen and 2 kg of phosphorus per ha. Hence, this study suggests for effective control of soil erosion at specific area which would occur under alternative management strategies and practices in order to minimize the costs related to fertilizer and environmental rehabilitation.

4. DISCUSSION

4.1. Soil Erosion Models and Their Potentials and Challenges

Soil erosion is the most serious causes of land degradation have influenced tremendous pressure on productivity and environmental stability of arid and semiarid areas. Serious impacts led the demand for conservation and management measures to reduce the magnitude of soil loss and the extent of its associated impacts in many parts of the arid and semiarid areas. There are many models in existence estimating soil erosion. The USLE has the advantage of being less data demanding than other models. A wide range of models that differ in their data requirement for model calibration, application, complexity and processes considered are available for use in predicting soil loss (Merritt et al., 2003). Physically based spatially distributed soil erosion models can be used to quantitatively determine the amount of soil loss from watersheds and also to identify critical soil loss source areas (De Roo, 1998; Emrah et al., 2007). The successful application of such models, however, depends on the availability and quality of data for calibration and validation (De Roo, 1998; Stefano et al., 1998; Takken et al., 1999). Such problems are more pronounced in developing regions where data availability is scarce, existing data are not easily accessible and data collected and stored are mostly in different formats. In addition, more complex models do not necessarily perform better for watershed-scale management purposes, mainly because input errors can increase with increasing model complexity (Favis-Mortlock, 1998; Mitas and Mitasova, 1998a; Jetten et al., 2003; Merritt, et al., 2003).

Empirical models are frequently used in preference to complex physically based models as they can be implemented in situations with limited data and parameter inputs, particularly as a first step in identifying sources and rate of soil loss (Merritt et al., 2003). However, such models

cannot be directly applied to environments other than those for which they were developed, and extrapolation of results from larger-scale plot-level to small-scale watershed level application is difficult. It is, therefore, necessary to identify models that are not very much simplified and under-represent the physical basis or not too complicated and very expensive to implement. The best example is USLE, which is identified and fit to apply in the case of the study area of Medego watershed, northern Ethiopia. The USLE is an empirically based model developed in the United States by using data on soil erosion rates. This equation has certain limitations but still is the best available method which is used most widely for estimating soil losses as average annual mass per unit area as a function of the major factors affecting sheet and rill erosion in data scarce areas of developing countries. As all landscape positions are not equally sensitive to erosion, one important approach to tackling the problem of erosion could be identifying where the sources of most of the soil loss are in a watershed (Dickinson and Collins, 1998; Kim et al., 2007). Identification of potential areas of erosion for appropriate management interventions to tackle the major causative factors at their specific locations is, therefore, imperative from an economic, management and sustainability point of view. This study was attempted in indicating the areas or landforms of high soil loss in Medego watershed, northern Ethiopia.

4.2. Soil Loss and the Influencing Factors in Medego Watershed

It is a fact that environmental degradation has been a problem in Tigray region, northern Ethiopia. The land surfaces in the region is mainly a reflection of the past erosion processes. The main causes of soil erosion in the area among others were out lined by different researchers ([Hurni, 1985; Gebresilassie, 1996, Tilahun, 1996; Tamene, 2005) and even witnessed by farmers as over-cultivation, deforestation, over grazing, steep topography, high rainfall intensity, unwise land use and management. This is evident by the huge amount of soil loss, by water erosion and very low productivity of the farm lands. Therefore, to rehabilitate the environment and enrich it to a meaningful level, a concerned effort on SWC program has been carried out by the community coordinated by of bureau of agriculture under the umbrella of the Tigray Regional Government, northern Ethiopia. In the name of SWC program, various types of physical and biological SWC measures have been undertaken in the study

watershed. These activities are: watershed treatment as area enclosure, afforestation, trench; reclamation of big gullies using check dams, biological; moisture harvesting techniques on farms and degraded grazing lands like soil, stone and trench bunds; and soil faced stone bund on hillsides.

Soil loss in different landforms of the study watershed is influenced by erosion factors differently. For instance, the soil erodibility (K) factor of the landforms in the watershed is a function of soil texture, drainage condition and soil depth. These sub-factors can influence the soil color, which determined the value of K-factor in USLE, adapted from Hurni (1985). The landforms in the watershed have different in texture, drainage condition, soil depth, soil color, land cover, erosion controlling management practices and slope factors (Table 3). Fine texture soils are dominated on flat land areas where as coarser textural class increases with increasing steepness. The same trend was observed for the soil depth with deeper soil on flat areas and shallow soil on high slope gradient landforms. The drainage condition is extremely high on steeper landforms and poor on flat area of the watershed. Therefore, the principle of Hudson (1992) that describe as fine soil particles resist to detachment by raindrops but they are susceptible to transport easily is soil drainage dependent. This is because if the landform is poor in drainage, so the probability of transporting by waters the fine particles long distance leaving the original area is too low. Transportation and deposition processes are almost balanced in such occasions. Drainage is affected by the slope factor. That is why soil loss estimated on flat landform is below the minimum tolerable soil loss (2 ton ha^{-1} yr^{-1}) determined by Hurni (19985) for Ethiopia condition. This is the lowest soil loss as compared to the other landforms in the watershed (Table 4). Sand dominant soil textures are common on higher slopes of the watershed. Even though they are coarser to transport as compared to clay texture due to high soil drainage condition of steep slopes, they are susceptible to erosion in the watershed.

Of course, the management practices in the watershed also play its own great role in the magnitude of soil loss. Landforms with well land cover indicated less soil loss. Because it dissipates the energy from rain drops and also decreases the volume and velocity of runoff effect. Soil loss estimated from landforms with very step slope (> 50%) in the study watershed is smaller than slopes

in the rage of 15-30% and 30-50%. The reason is cover factors and land managements factor are better in the very steeper slopes of the watershed. This includes less human and livestock interferences, intensive terraces and relatively better vegetation cover of bushes and shrubs. Therefore, the overall implication of this study is that after the implementation of SWC measures the amount of soil loss in a given land unit is decreased in many parts of the landforms by more than 50% in the watershed as compared to the high values indicated in the past studies in northern Ethiopia (e.g., Hurni, 1985; 1990; 1993; Tekeste and Paul, 1989; Gebreselasie, 1996)). However, the present soil loss amount has also a significant influence on the overall productivity of the study watershed unless the correct measures on the targeted landforms are undertaken. This is because as compared to the soil formation in the region which is not more than 2 ton ha^{-1} yr^{-1} (Hurni, 1985); the present soil loss estimated in Medego watershed, northern Ethiopia is not neglected or it is very big. Therefore, base on the landforms identified in this study, soil conservation planning should be undertaken to address the problem of erosion in areas having large soil loss as areas of prioritization in the future.

5. CONCLUSION

The entire watershed area experienced intensive rainfall which coupled with steep gradient slopes, cause highly erosive runoff as in many other arid and semi-arid areas of Ethiopia. It is this high runoff and soil detachment that is responsible for the high rate of soil erosion at Medego watershed, northern Ethiopia that range from 1.59 – 35.43 tons ha^{-1} y^{-1}. There is a need to regulate this soil loss by all possible means so as to decrease the existing amount of soil loss and enhancing watershed rehabilitation and productivity. Suggested watershed rehabilitation as long and short-term measures should be included the following: As long-term measures re-vegetation of denuded hill slopes with trees and perennial grasses such as vetiver strips and belts; introduction of an agro-forestry program that is compatible with crop, livestock; and forestry development; where as short-term soil and water conservation measures are given due attention to: cut-off drains which need to construct that intercept runoff; constructing and maintenance stone and soil bund and trenches on proper slopes and soils and integrating with vegetation intensively. This has to include interventions such as inter-bund management, bund stabilization, buffer zone establishment and re-bank re-vegetation; and gully control by both vegetative and structural measures should be being intensively implemented.

As a result of the implementation of SWC, the hydrological behavior of the watersheds is improved such as base flow in streams and springs increased, sediment load to reservoirs reduced, crop yield improvement due to soil moisture enhancement, vegetation cover improvement and increased availability of forage for livestock were observed. These are some of the indicators of the effectiveness of the implemented soil and water conservation practices in the study watershed. However, maintenance of the existing SWC and introducing additional appropriate land management practices and rules should be given attention by concerned bodies in order to decrease and totally stop the rate of soil loss and then to increase the total biomass production in the watershed, even though the biggest rate (35.43 tons ha^{-1} yr^{-1}) of soil loss is coming from landforms having slopes 30-50% and the lowest soil loss is from slope less than 2%. Therefore, to maximize the available resources in targeting the effect of water erosion on soil loss, those landforms and land uses having large rate of erosion should be given first priority during the introduction of intensive and well designed SWC interventions at Medego watershed, northern Ethiopia.

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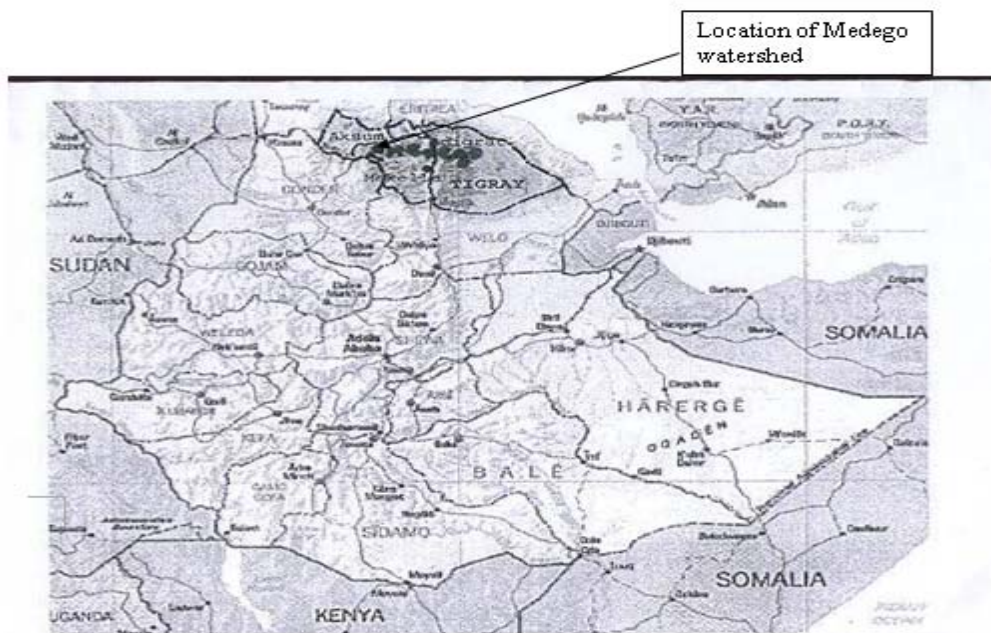

Fig 1: Map of Ethiopia with Tigray region and Medego watershed outlined.

Table 1

Land forms and their area coverage in Medego watershed, Lalay-Maychew district, northern Ethiopia.

land forms/ features	Slope range (%)	Area coverage (ha)
Flat plains	< 2	200
Undulating plains	2-8	300
Rolling land	8-15	50
Hill to rolling	15-30	290
Steep Mountains	30-50	200
Very steep escarpment	>50	50
Flat, flood prone area	< 2	1.5
Total		1091.5

Table 2.

Farmers own ranking of important tree and shrub in the order of importance at Medego watershed, Lalay-Maychew district, northern Ethiopia.

Column number*	1	2	3	4	5	6	7	8	9	10	11	12
Species use for	Soil improve-ment	fodder	Bee forage	fencing	Fire wood	charcoal	Constru-ction	Hand tools	Soil conserve-ation	shading	total	Score/rank
Che'a/Acacia abyssinica	1	3	4	4	4	2	2	4	3	3	30	4
Seraw/Acacia etbaica	3	2	1	2	5	5	1	4	3	3	29	6
Acacha/Acacia decurrens	3	5	4	3	4	3	4	1	3	4	34	1
Eika/Agave sisalana	-	1	2	5	-	-	1	-	5	-	14	11
Ere/Aloe berhana	-	1	4	4	-	-	-	-	5	-	14	11
Tebeb/Becium gradiflorum	4	-	5	-	2	-	1	-	3	-	15	9
Agam/Carrissa edulic	2	1	-	3	3	1	1	1	2	1	15	9
Tahsus/Dodonea angguistifolia	3	2	3	3	3	4	3	5	4	3	33	3
Bahrizaf/Eucalyptus comoldulensis	3	5	2	1	4	3	5	3	2	2	30	4
Kulkual/Euphorbia abyssinica	-	-	3	5	1	-	3	-	4	4	20	7
Awlie/Olea europea	2	1	2	1	5	5	5	5	3	5	34	1
Beles/Opuntia ficus indica	-	5	2	4	-	-	-	-	5	-	16	8

- = no/zero value; *(1-5) = 1 with the lowest value and 5 with the highest value for column 1 up to 10 but it is the reverse of this in column 12 which is the top rank starts with 1 and the last/lowest rank ends with 11. Column 11 is sum of columns 1 up to 10.

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Table 3
Selected soil characteristics, average slope length (L) and gradient (S), land cover (C) and management
(P) practices collected for different landforms at Medego watershed, northern Ethiopia

Land form	Soil color	Ave. L (m)	Ave. S (%)	C-factor*	P-factor*	Soil depth	texture	drainage
Flat plains	Black and brown	25	2%	Ethiopian teff (0.25)	Ploughing on contour (0.90)*	deep	Clay loam	poor
Undulating plains	Black and red	22	5	Cereal, Ethiopian teff and degraded grass (0.15)	Ploughing on contour and strip cropping (0.73)	Moderately deep	Sandy loam	moderately
Rolling land	Brown and red	18	12	Badlands soft, pulses and degraded grass (0.2)	Ploughing on contour, stone cover 40% and terraces (0.73)	shallow	Sandy silt	High
Hill to rolling	Brown and yellow	25	15	Scattered forest, degraded grass, badlands soft and bush (0.13)	Stone cover 40%, protected areas and terraces (0.63)	Very shallow	sandy	Extremely high
Steep mountains	Red and yellow	15	40	Scattered forest and badlands soft (0.22)	Stone cover 80%, protected areas and terraces (0.53)	Extremely shallow	sandy	Extremely high
Very steep mountains	yellow	10	60	Badlands hard and bushes/shrub (0.04)	Stone cover 80% and terraces (0.53)	Extremely shallow and rock out crops	Coarse sand	Extremely high
Flat, flood prone area	black	20	2	Dense forest and Ethiopian teff (0.13)	Dense intercropping (0.7)	Very deep	clay	Extremely poor

* Numbers in parenthesis are the mean values of more than two C or P practices based on interpolation from Hurni (1985) and Gebresilassie (1996).

Table 4.
KLSCP factors values adapted based on Hurni (1985); Gebreselasie (1996) to land forms and land use at
Medego watershed, northern Ethiopia. R factor is 357 for all landforms in the watershed.

Landform	land use	K-factor	L-factor	S-factor	C-factor	P-factor	tons ha^{-1}y^{1}
Flat plains	cultivated	0.18	1.1	0.1	0.25	0.90	1.59
Undulating plains	cultivated; some grazing	0.20	1.0	0.4	0.15	0.73	3.13
Rolling land	cultivated; some grazing	0.23	0.9	1.0	0.20	0.73	10.88
Hill to rolling	scattered natural forest, reforestation, grazing and area closure, some marginal area	0.25	1.1	1.6	0.13	0.63	12.86
Steep mountains	grazing area, some closed area, marginal area	0.28	0.8	3.8	0.22	0.53	35.43
Very steep mountains	Protected area with bushes/shrubs	0.30	0.7	4.8	0.04	0.53	7.63
Flat, flood prone area	Rain fed and irrigated land, dense eucalyptus trees and check dams and biological measures in gullies	0.15	1.0	0.1	0.13	0.70	4.87
Mean soil loss							9.63