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Research Article

Review of Soil Erosion Risk For Soil and Water Conservation Planning Under Ethiopian Condition

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ABSTRACT

Soil erosion is one of the major factors affecting sustainability of agricultural production in Ethiopia. This paper reviews Ethiopia's experience and research progress in soil erosion risk for Soil and Water Conservation planning. In most findings conducted at Ethiopian watershed possibilities of high soil lose and risk was reported. Their findings revealed that the study areas are facing different problems such that forest transformation, which is very likely intensified by the demand for subsistence agricultural land. Most of the parts of these watersheds have experienced intensive soil erosion behavior, which is beyond the tolerable soil loss level. This threatens the annual crop production and the productivity of the land impacting the local farmers' food security. Analysis of a compilation of soil loss rates due to sheet and rill erosion at plot and catchment scales indicates that this soil degradation process varies strongly spatially, with a mean soil loss 29.9 t ha −1 yr −1.The highest rates were observed in Anjeni (110 t ha −1 yr −1) and Chemoga (102 t ha −1 yr −1) of the Upper Blue Nile Basin. Studies in the northern Ethiopian highlands and the Central Rift Valley of Ethiopia reported larger erosive power of rainfall as compared to elsewhere in the world.FAO (1986) estimated of gross annual soil loss nationwide of 1.9 × 10 9 t of which 80% originates from croplands. Hurni (1988) estimated a nationwide annual gross soil loss of 1.5 × 109 t, extrapolating data obtained from six SCRP research stations in which the highest loss is from croplands (42 t ha −1 yr −1). Sonneveld et al. (2011) provided a tentative nationwide mean annual soil loss map combining the results of different model estimates. They stated that soil loss varies remarkably from 0 t ha −1 yr −1 in the eastern and southeastern parts of Ethiopia to more than 100 t ha −1 yr −1 in the northwestern part of the country. Hence, review on identifying and prioritizing erosion susceptible areas for soil conservation measures are quite essential. Reviewing or quantifying the effects of the soil loss helps to substantiate investment in sustainable land management for the benefits to land users. Appropriate soil conservation measures bring economic advantages to the land users. Review on amount of soil loss and the status of the existing soil conservation measures can be realistic for farmers and policy makers if expressed in terms of understandable value.

Keywords: Soil erosion risk; Soil and water conservation; Annual soil loss; Ethiopia

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. Livelihood of human kind is closely linked to soil and soil contributes food, clean water, clean air, and are a major carrier for biodiversity [1-3]. Most of the people in the world remain heavily dependent on soil resources as their main livelihood source that lead to high soil erosion. The high erosion rates are affecting mainly the developing countries due to intensive cultivation, deforestation, ploughing of marginal lands and extreme climate hazards [4-6]. Soil erosion is worldwide environmental problem that threatens the lives of most smallholder farmers [7-9]. Soil erosion rates beyond the tolerable limit changes in the hydrological, biological, geomorphic process and geochemical cycles, which result lack of the services that the soil offers to the human beings [7-11]. On cultivated lands, appropriate soil conservation mechanisms supported with Vegetation are efficient strategies to control soil losses [12-13]. About 80% of the current agricultural land degradation is caused by soil erosion globally [14-15]. Sustainable agricultural practice is challenged by severe soil erosion, as it reduces on-farm soil productivity and causes food insecurity [16-18]. In most developing countries, including Ethiopia, anthropogenic activities trigger soil erosion [19-20].

With the present Ethiopian population of 90 million with a growth rate of 2.7% (CSA, 2015), about 80% of the population depends on agricultural practices leading to very high population pressure on the land. Together with corresponding high live- stock

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density, the agricultural sector is leading to serious overuse of the land. As many literatures documented, soil erosion in highlands areas is seen as a direct result of the historical human settlement in Ethiopia because of its favorable climatic conditions, political factor and fertile soil [21-23]. Soil erosion in Ethiopian highlands is one of the biggest problems resulting in both on-site and off-site effects. This phenomenon has provoked by high population density, overgrazing, deforestation, land fragmentation, steep terrains, and cultivation on marginal and fragile lands. Such factors aggravate soil erosion and productivity declines, resulting in food insecurity of small holder farmers. The annual rate of soil loss in the country is higher than the annual rate of soil formation rate [24,25]. Annually, Ethiopia losses over 1493 million tones of topsoil from the highlands due to erosion which can add about 1.5 million tons of grain to the countries harvest [26-29]. About 43% (537,000 km^2) of the total highland areas of Ethiopia are highly affected by soil erosion with an estimated average of 20 t ha −1 yr −1 and measured amounts of more than 300 t ha $^{-1}$ yr $^{-1}$ on specific plots [27,28]. Whereas the Blue Nile basin lost fertile soils with a rate of 131 million t ha $^{-1}$ yr $^{-1}$ soil [30]. Lack of appropriate soil conservation measures and poor land use management have played a great role for serious soil erosion problems in the country.

In the past, It is also reported 130–170 t ha $^{-1}$ year^{-1} soil loss on a similar land use in the northwestern highlands of Ethiopia. In earlier estimates, the average soil loss on cultivated croplands in the Ethiopian highlands was 42 t ha $^{-1}$ year^{-1} and 35 t ha $^{-1}$ year^{-1} for all lands [31]. However, the acceptable soil loss that can maintain an economic and a high level of production [31-33] ranges from 5 to 11 t ha $^{-1}$ year^{-1} [34]. Every year, an estimated 1.9–3.5 billion tons of topsoil in Ethiopian highlands has been lost and as a result about 20,000–30,000 ha of cropland was taken out of production due to severe soil erosion in the earlier decades [16]. It is also indicated that 1.5 million tons of soil has been lost in the Ethiopian highlands each year, which also has resulted in a significant loss of grain from the country's annual harvest. Estimate through modeling work also suggests that soil erosion in Ethiopia will reduce the potential production of the land by 10% in 2010 and by 30% in 2030. As a result, the value added per capita per annum in the agricultural sector goes down from US$372 in 2010 to US$162 in 2030 [35]. These clearly show soil erosion is a serious problem in the highlands. As a result of soil erosion, poverty and food insecurity are concentrated in rural areas (MoARD 2010). Thus, in order to achieve food security, poverty reduction and environmental sustainability in the country reversing soil erosion is a high priority [15-18]

In order to reverse soil erosion, several efforts have been exerted since the 1970s [36]. However, past soil conservation efforts did not bring significant changes to the ongoing soil degradation problems [37-39]. Most recently, watershed management is an approach followed by the government of Ethiopia to protect soil from erosion in particular and to reverse land degradation in general [38]. Although dramatic reduction has been made in arresting soil erosion [39-40], the approach has not been supported with intervention prioritizing techniques that identify highly susceptible areas using geospatial analysis.

Hence, review on identifying and prioritizing erosion susceptible areas for soil conservation measures are quite essential. Reviewing or quantifying the effects of the soil loss helps to substantiate investment in sustainable land management for the benefits to land users. Appropriate soil conservation measures bring economic advantages to the land users. Review on amount of soil loss and the status of the existing soil conservation measures can be realistic for farmers and policy makers if expressed in terms of understandable value.

General objective

The overall objective of this seminar paper is to review erosion risks for SWC planning under Ethiopian condition ultimately recommending strategies for sustainable soil and water conservation intervention so as to halt soil erosion and improve agricultural productivity.

Specific objectives

- To review soil erosion and its impacts nationally
- To review nature and extent of the problem
- To review annual rates of soil losses and severity in different parts of Ethiopia
- To recommending strategies for sustainable soil and water conservation planning so as to halt soil erosion

METHODOLOGY

The methods employed was based on the information gathered from secondary data such as from internet, books, articles, proceedings, literatures, cross referencing and journals of soil and water conservation, watershed and others related science. Because of the title is current issue of Ethiopia the most of data's is taken from internet access and other recent published journals and books. Several dozen studies were identified and reviewed. By using secondary data sources the risk erosion risks for SWC planning under Ethiopian condition ultimately recommending strategies for sustainable soil and water conservation intervention so as to halt soil erosion and improve agricultural productivity were discussed and concluded in attractive and scientific manner. The idea contents of published materials, who did what and who wrote what in relation to this topic was a major criterion to select secondary data sources.

REVIEW OF WORKS

Soil Erosion and Its Impacts in Ethiopia

Soil is being degraded at an unprecedented scale, both in its rate and geographical extent. Among the various forms of land degradation, soil erosion is the most serious problem, which results in soil nutrient depletion and loss of productive capacity of land. Soil erosion is the process of detachment of soil particles from the top soil and transportation of the detached soil particles by wind and/or water [40]. Soil erosion is environmental problem, which poses an ominous threat to the food security status of population and future development prospects of the country [41]. It is the most serious environmental problem affecting the quality of soil, land, and water resources upon which humans depend for their sustenance. In Ethiopia, the productivity of the agricultural sector of the economy, which supports about 85% of the workforce, is being seriously affected by soil productivity loss due to erosion and unsustainable land management practices. The average crop yield from a piece of land in Ethiopia is very low according to international standards mainly due to soil fertility decline associated with removal of topsoil by erosion. It is estimated that soil loss due to erosion of cultivated fields in Ethiopia amounts to about 42 t ha $^{-1}$ year $^{-1}$. According to an estimate by FAO (1986), some 50% of the highlands of Ethiopia were already "significantly eroded" in the mid-1980s and erosion was causing 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 about 30%. It is indicated that Ethiopia loses over 1.5 billion tons of soil each year from the highlands by erosion resulting in the reduction of about 1.5 million tons of grain from the country's annual harvest [42-44].

The persistent deterioration of the quality of the cultivated land in Ethiopia is reflected in degraded slopes, ever-expanding gullies, and associated fragmentation of farm fields. Besides its huge impact on on-site land productivity, soil erosion also causes rapid siltation of streams and reservoirs accelerating storage capacity loss of water harvesting schemes. The rapid water storage capacity losses of dams result in the waste of considerable investments incurred in their construction in addition to failure to achieve food security through surface water harvesting [45].

Nature and Extent of soil erosion

In most of Ethiopia, soil erosion by water is a fundamental problem. A casual visitor is usually amazed by the extent and severity of visible soil erosion of farmlands and grazing areas. Soil erosion is severe in the more barren and mountainous northern highlands. In Tigray (northern Ethiopia), the topsoil, and in some places the subsoil, have been removed from sloping lands, leaving stones or bare rock on the surface [45].

Sheet and rill erosion: Analysis of a compilation of soil loss rates due to sheet and rill erosion at plot and catchment scales indicates that this soil degradation process varies strongly spatially, with a mean soil loss 29.9 t ha $^{-1}$ yr $^{-1}$ (SD = 30.2 t ha $^{-1}$ yr $^{-1}$, n= 25) The highest rates were observed in Anjeni (110 t ha $^{-1}$ yr $^{-1}$) and Chemoga (102 t ha $^{-1}$ yr $^{-1}$) of the Upper Blue Nile Basin. Variation in mean annual rainfall was found to explain 35% of the soil loss variability among the case study sites. Studies in the northern Ethiopian highlands (Nyssen et al., 2005) and the Central Rift Valley of Ethiopia [46]. It is reported larger erosive power of rainfall as compared to elsewhere in the world. It is indicate a likely increase in precipitation and extreme precipitation events throughout the 21st century particularly in the highlands [47].

The considerable effects of land use on soil loss were reported [48], with soil loss rates of 38.7 t ha $^{-1}$ yr $^{-1}$ from rangeland as compared to 7.2 t ha $^{-1}$ yr $^{-1}$ from cropland. They attributed the higher soil loss in rangeland to increased runoff resulting from intensive grazing and soil compaction, whereas soil tillage supports infiltration and causes less runoff and soil loss in croplands. There is also strong variation in soil loss rates within certain land use types located in the same drainage basin, implying the heterogeneous nature and effects of other environmental factors, for which no data are available

Very few estimates are available about the overall soil loss rates at regional or national scale. FAO (1986) estimated of gross annual soil loss nationwide of 1.9×10^9 t of which 80% originates from croplands. It is estimated a nationwide annual gross soil loss of 1.5×10^9 t, extrapolating data obtained from six SCRP research stations in which the highest loss is from croplands (42 t ha $^{-1}$ yr $^{-1}$). Tentative nationwide mean annual soil loss map combining the results of different model estimates. They stated that soil loss varies remarkably from 0 t ha $^{-1}$ yr $^{-1}$ in the eastern and southeastern parts of Ethiopia to more than 100 t ha $^{-1}$ yr $^{-1}$ in the northwestern part of the country, but they did not note what causes this huge spatial variation. From the above studies, we can understand that the soil loss estimation at national level is still tentative and inconsistent [49-50] (**Figure 1**).

Usle: Universal Soil Loss Equation

Psiac: Pacific Southwest Interagency

Agnps: Agricultural Nonpoint Source Pollution model.

Several interacting factors are responsible for the high erosion and land use dynamics in Ethiopia. The environmental history of north Ethiopia with particular reference to the pre-Aksumiteto post-Aksumite period (500 BC–900 AD) [51] and concluded that during this period the region underwent effects linked to demographic development, climate change, and changes in vegetation cover, all of which contributed to soil erosion. Pollen and charcoal analysis of sediment cores from two lakes in the highlands of north Ethiopia provide evidence that the vegetation has changed in response to human impacts during the last 3000 years [52].

A direct relationship between population pressure and land degradation such that, under comparable physical conditions, heavily eroded areas occur in highly populated regions [53]. A shrub land vegetation and environmental data analysis in west Shewa of Central Ethiopia showed that shrub land vegetation may have expanded from lower elevations with drier site characteristics as forests gradually disappeared [54]. The agricultural system in the Adwa district of north Ethiopia was influenced by elevation, documented by the positive correlation between elevation and human population, livestock densities [55], and cropland area. A study in the central Rift Valley of Ethiopia [56]. It is pointed to a marked increase in soil erosion rates from 1973 to 2006, with annual rates of 31 t ha $^{-1}$ in 1973 and 56 t ha $^{-1}$ in 2006. They attributed the increasing soil erosion rates to the conversion of forests or woodlands to croplands.

Gully erosion: In Ethiopia, discontinuous gullies which generally develop on low slope gradients (2 – 9%; and continuous valley-bottom gullies (ephemeral river channels), formed by intense hydraulic erosion processes typically expanding upslope are identified as the two main types of gullies [57].

Possible causes for gully erosion in the study region include human activities such as road construction that lead to a diversion of concentrated runoff to other catchments [45], disintegration of waterfall tufas [58], land use changes [57-59], dry spells, and the

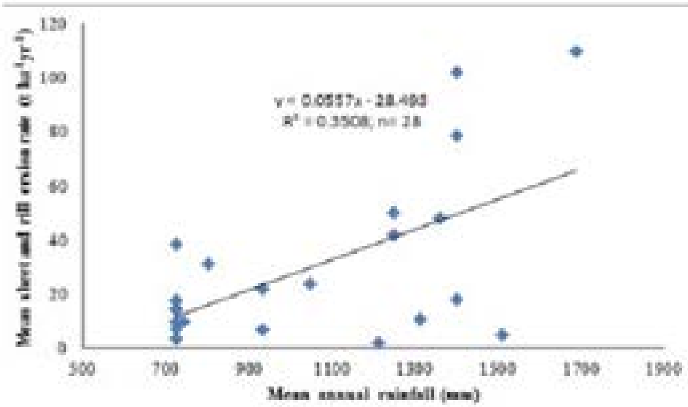

Figure 1: Relationship between mean annual rainfall (mm) and mean soil loss rates (t ha $^{-1}$ yr $^{-1}$) for 28 case studies sites found across Ethiopia.

presence of vertic soil characteristics [60]. Rates of gully erosion vary with the stage and management condition in the catchment. Extremely high gully erosion rate of 530 t ha $^{-1}$ yr $^{-1}$ for the Debre-Mawi watershed in northwest Ethiopia (17.4 ha drainage basin size) using semi-structured farmer interviews, remote sensing images, and measurements of current gully volume. This rate was approximately 20 times larger than the measured sheet and rill erosion rates at the same study site. A roughly similar gully erosion rate of 1.7 t m^{-2} (ca. 566 t ha $^{-1}$ yr $^{-1)}$ was reported by Daba et al. (2003) for the Damota catchment in eastern Ethiopia (9 km^2 drainage basin size) on the basis of an analysis of aerial photographs from two different dates (1966 and 1996).

Studies in north Ethiopia show lower gully erosion rates, and the rates have been decreasing in recent years. For example, It is reported an average gully erosion rate of 6.2 t ha $^{-1}$ yr $^{-1}$ over a 50-year time span, and this rate has decreased to 1.1 t ha $^{-1}$ yr $^{-1}$ since 1995 [61]. It is reported medium- to long-term (1–47 years) head cut retreat rates to be 10 times higher than short-term ones on the basis of their analysis of archival terrestrial and aerial photographs. The assessed a region-wide change in gully and river channel morphology in Tigray over the period 1868–2009, using historical photographs and integrating some gully cross-section measurements from 2006 to 2009. They distinguished three hydrological regimes of the catchments: oversized channels stage (1868 to ca. 1965), accelerated channel dynamics stage due to persistent clearance of vegetation (ca. 1965–ca. 2000), and stabilized channels stage as a result of large-scale implementation of SWC measures (ca. 2000–2011). In another study, study on long-term changes in gully network in the same study region over the period 1964-2010 and the results validate the above findings. They reported that installation of check dams have reduced the cross-sectional areas of the gully channels (through sediment deposition) by an average of 33.5 % compared to untreated gully channels, thereby reducing mean channel depth by one third [62-64].

Overall, most of the gully erosion studies conducted in Ethiopia are based on the interpretation of relatively low-resolution aerial photographs or in combination with satellite images and repeated photographs supplemented by data obtained from questionnaires. Detailed historical records on gully erosion are lacking. Moreover, most of the case studies so far are concentrated on the Tekeze Basin, northern Ethiopia, where rainfall depth is relatively limited and where a positive influence of environmental management is clearly evident. The limited case studies from other parts of Ethiopia show that the gully erosion is more severe in those parts of the country, and SWC practices in those areas are also generally limited.

Sediment yield: Data on SY, defined as the total sediment outflow from a catchment measurable at a point of a reference and for a specified period of time, are rarely available for Ethiopian rivers [65]. The few available studies rather show significant SY variability and high associated impacts. An analysis of sediment discharge data for 10 medium-sized catchments (121–4590 km^2 drainage basin size) in sub-basins of the Giba River, located in Tigray, revealed SY values ranging from 5 to 66 t ha $^{-1}$ year^{-1} [55]. Reservoir sediment surveys conducted for 14 Micro-dam watersheds in northern Ethiopia show a large spatial variation among the catchments, ranging from 2 to 19 t ha $^{-1}$ year$^{-1,}$ which also ranged in drainage basin size from 0.71 to 67 km ^{2} [66]. Such high SY values have drastic consequences for the life expectancy of many reservoirs in the Ethiopian highlands [67].

The poor availability and reliability of SY data for Ethiopian rivers remains a major bottleneck for a better understanding of the dynamics and drivers of SY variability in the region [68]. It is also stressed that the application of better soil erosion models in Ethiopia is restricted by data paucity. On the other hand, sediment yield analyses made at regional scale relying heavily on soil loss rates measured at plot scale could lead to wrong conclusions due to the strong dependence of erosion process rates on spatial scale [69]. Moreover, despite the significant contributions of gully erosion to the overall sediment budget [68-70], previous studies have not accounted for this process so far. It is emphasized the need for the maintenance and monitoring of existing hydrometric stations in addition to the establishment of new ones, which are needed to reflect the different eco-hydrological environments in Ethiopia. **(Figure 2)**

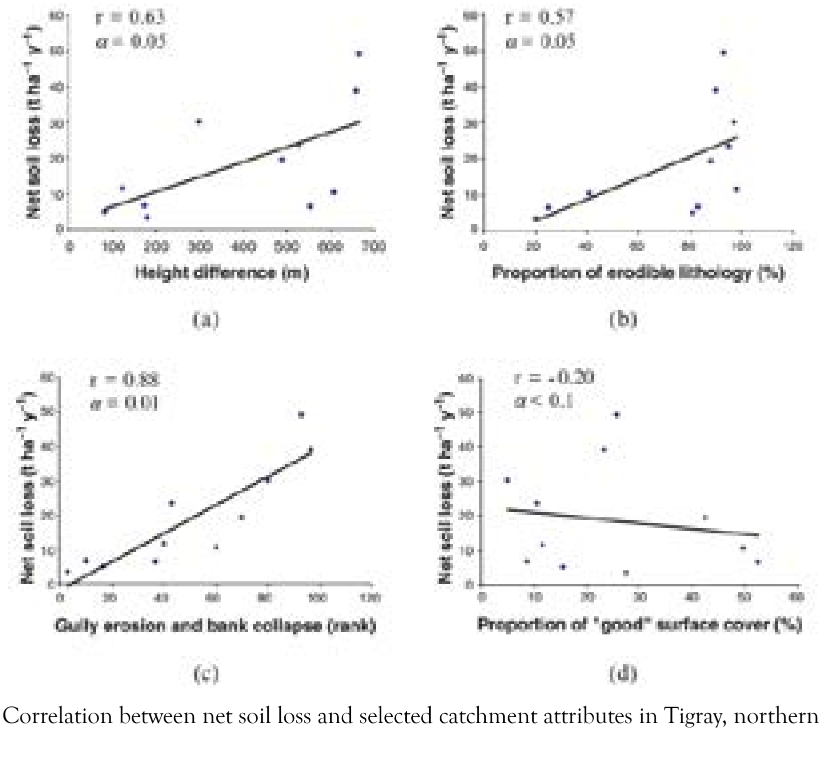

Figure 2: Correlation between net soil loss and selected catchment attributes in Tigray, northern Ethiopia

Annual Rates of Soil Losses and severity in different part of Ethiopia

The reservoir survey data for the different sites in the north Ethiopia shows that net soil losses from catchments ranges from about 3–49 t ha $^{-1}$ year $^{-1}$ with a mean value of 19 t ha $^{-1}$ year $^{-1}$. The relatively high soil-loss variability is due to the wide contrast in environmental variables of the catchments such as terrain, lithology, surface cover, and degree of gully erosion. The magnitude of annual soil loss observed in the study region is generally higher than the "tolerable" soil loss of about 2–18 t ha $^{-1}$ year $^{-1}$ estimated for Ethiopia [71]. All the erosion estimates of the studied sites are above the minimum tolerable limit and five of the catchments have an annual soil loss above the maximum tolerable limit. The soil-loss rates are also beyond the rate of soil formation of 3–7 t ha $^{-1}$ year $^{-1}$ [70]. In addition, the mean net soil loss of 19 t ha $^{-1}$ year $^{-1}$ is high compared with the mean global (15 t ha $^{-1}$ year $^{-1}$) and mean African (9 t ha $^{-1}$ year $^{-1}$) sediment-yield rates [72] **(Table 1).**

Soil loss estimation within Geleda watershed found in the Blue Nile basin: In the study conducted at Geleda watershed which is found in the Blue Nile basin the mean annual soil erosion rates ranged from 0 t ha^{-1} year $^{-1}$ in plain areas to 237 t ha^{-1} year $^{-1}$ in the hilly terrains of the watershed. The result shows that the entire watershed looses a total of about 0.16 million tones of soil annually. In terms of exposure to the risk of erosion, which were set with the Authors consideration, about 78.75% of the watershed is characterized low soil erosion rate, which is 0–11 t ha^{-1} year $^{-1}$ year $^{-1}$and such areas can be considered low risk areas. The remaining areas are categorized as moderate risk areas (13.93%) with a rate of 11–18 t ha^{-1} year, high risk areas (2.76%) with a rate of 18–30 t ha^{-1} year $^{-1,}$ very high risk areas (3.73%) with a rate of 30–50 t ha^{-1} year $^{-1}$ year −1and severely affected areas (0.83%) with a rate of 50–237 t ha^{-1} year $^{-1}$ year $^{-1}$ The average soil loss rate estimated for the entire watershed was 23.7 t ha^{-1} year $^{-1}$, which is comparable to the average soil loss rate for the highlands (18 t ha^{-1} year $^{-1}$) [41].

Table 1: Annual rate of soil loss from the study catchments in northern Ethiopia.

Catchment name	Area (km')	Soil loss (t ha-1 year')
Adiakor	2.8	5.0
Adikenafiz	14.0	49.4
Gerebmihiz	19.5	39.2
Gerebsegen	4.0	11.7
Gindae	12.8	19.6
Grashito	5.6	30.2
Korir	18.6	10.6
Laela)'\vukro	10.0	6.5
Maidelle	8.7	23.6
Majae	2.8	6.8
Teghane	7.0	3.5

Annual soil loss Estimation within Koga Northeast Wollega Ethiopia: Soil erosion assessment in Northeast, the rainfall erosivity R factor was 1045.63 MJ mm ha $^{-1}$ h $^{-1}$yr $^{-1}$ given the mean annual rainfall is 1875 mm. K factor, L factor, S factor [73], C and P factors vary with land cover types. The annual rate of soil erosion (A) is in the range of 4.5–65.9 Mg ha $^{-1}$yr $^{-1}$. It was 4.5 Mg ha $^{-1}$yr $^{-1}$ in forestland, 37.6 Mg ha $^{-1}$yr $^{-1}$ in shrub land, 22 Mg ha $^{-1}$yr $^{-1}$in grassland, and crop land 65.9 Mg ha $^{-1}$yr $^{-1}$. As expected, soil loss is maximum on cropland land and minimum on forestland. Perhaps, the annual soil erosion rate in cropland is very highly severe (50–80 Mg ha $^{-1}$yr $^{-1}$). This land use was hence assigned the first priorities, in order of mention, for conservation planning-account for about 69 % of the total soil loss from the study area **(Table 2).**

Annual soil loss estimation within Koga Watershed North West Ethiopia: On average the rate of annual soil loss in the Koga watershed was predicted as 30.2 t ha $^{-1}$ in with specific spot exhibiting losses of 716 tones at the upper part of the watershed [74]. The annual soil loss computed in Koga watershed is higher than the normal Soil loss tolerance. The total soil loss was modeled as 10.8 million t ha $^{-1}$ from 29,524 hectares of land. This research result has the same pattern with previous researches conducted on similar agro ecological zones. For instance, FAO estimated 100 t ha $^{-1}$ yr $^{-1}$ soil loss from cropped lands in the highlands of Ethiopian in which Koga watershed is included. Soil Conservation Research Program (SCRP) also conducted a study at Anjeni research station showed that the annual soil loss rate to be 131 - 170 t ha $^{-1}$ [75]. The spatial distribution of annual soil loss estimates using RUSLE model that ranges from 12.1 t ha $^{-1}$ at the outlet to 456.2 t ha $^{-1}$ at the upper part of the study area for 2015. High soil loss rates were observed at the upper parts of the study area and along the sides of rivers. Soil loss rates from these areas were above 50 t ha $^{-1}$ yr $^{-1}$.The statistical values in table 3 revealed that the rate of soil loss has a significant correlation with the slope conditions in the area **(Table 3).**

Annual Rates of soil losses and severity in the Chaleleka Wetland watershed, Central Rift Valley of Ethiopia: Using RUSLE in combination with GIS allowed analysis of erosion problems in the Cheleleka wetland watershed [76]. Their findings revealed that the study area is facing forest transformation, which is very likely intensified by the demand for subsistence agricultural land. Most of the parts of this watershed have experienced intensive soil erosion behavior, which is beyond the tolerable soil loss level. This threatens the annual crop production and the productivity of the land impacting the local farmers' food security [77-78]. The erosion may also have off-site consequences in the wetlands and have the possibility to modifying its nature and function [79] **.**

The soil loss rate map shows various soil erosion rates with an estimated soil loss ranging from 2.5 t/ha/yr in the plain areas and those covered with plantation forests, such as the Cupressus lustanica and Eucalyptus plantations [80], to a little over 60 t/ha/yr in the areas of agricultural lands, waterways and drainages. The total annual soil loss in the study area (from an

Table 2: Annual soil erosion rate and severity classes among di erent land uses in Northeast.

LULC	Soil Loss (Mgha^{-1} yr^{-1})	Severity Class	Area (ha)	% of Total
Cropland	65.87	Very high	10363.3	69.18
Shrubland	37.64	High	21.51	0.14
Grassland	21.95	Moderate	952.0	6.36
Forestland	4.47	Low	3164.5	21.13

Table 3: Annual soil loss severity classes.

Soil loss (t ha-1yr-1)	Severity class	Area (ha)	Percent of total area	Total Annual soil loss (ton)	Percent of total soil loss	Average Slope (%)
0-5	Low	19,341.2	62	671,849	6	3
5-20	Moderate	3,430.7	11	332,427	3	6
20-50	High	939.8	3	198,645	2	IO
50-100	Very High	651.2	2	298,361	3	12
100-150	Severe	1,706.9	6	1,286,745	12	17
150-716	Extreme	4,924.3	16	8,077,658	74	26
Total				10,865,685	100	

Table 4: Annual soil loss rates and severity classes with their conservation priority in Wondo Genet watershed in the eastern highlands.

Soil Loss(t/ha/y)	Severity Classes	Priority Classes	Area (ha)	Total Area Coverage (%)	Total Annual Soil Loss (tones)	Soil Loss(%)
0-5	Low	VII	927.27	581.94	2318.175	3.62
5-11	Moderate	VI	153.18	6.20	1225.44	1.91
11-20	High	v	209.16	8.50	3241.98	5.06
20-30	Very high	IV	208.26	8.40	5206.5	8.13
30-45	Sever	111	231.75	9.40	8690.625	13.58
45-60	Very Sever	11	160.29	6.50	8415.225	13.15
>60	Extremely Sever	I	581.94	23.50	34916.4	54.54
Total			2471.85	100.0	64014.345	100.00

estimated area of 2472 ha) was about 64014.345 tons. The average annual soil loss for the entire district was estimated at 26 t/ha/yr **(Table 4).**

Additional findings on annual soil lose: Many researchers conclude their findings about erosion risk by estimating annual rates of soil losses and severity in different part of Ethiopian water shed at different time such that, the average soil loss rate in watershed in the northwestern highlands (30.4 t ha $^{-1}$ year $^{-1}$) and FAO (1986) reported an average soil erosion rate of 35 t ha $^{-1}$ year $^{-1}$for the central and northern highlands. An average soil erosion rate of 93 t ha $^{-1}$ year $^{-1}$in Chemoga watershed of the Blue Nile basin in the northwestern highlands. In a recent study in Koga watershed of the Blue Nile basin reported an average soil erosion rate of 47.4 t ha $^{-1}$ year $^{-1}$ [81-82]. It is pointed out that about 50% of the Lake Tana basin is exposed to high to very high risk of soil erosion rates, in some cases reaching as high as 256 t ha $^{-1}$ year $^{-1}$. A similar assessment in northwestern highlands and reported a very high rate of erosion ranging from 130 to 170 t ha $^{-1}$ year $^{-1}$ [83] **(Table 5).**

High erosion rates on steep slopes were also reported in other similar studies such as in Medego watershed where the slope ranged between 30 and 50% [84-86], erosion rate of more than 80 t ha $^{-1}$ year $^{-1}$on steep slope areas in the Borena watershed **(Table 6).**

CONCLUSION

Soil erosion is a global issue that threatens human livelihoods and civilization. A number of factors contribute to the high rates of soil loss at global, regional, and local levels. Climate, slope, soils, surface cover, and land management are the most important. Land misuse, deforestation, and overgrazing lead to severe erosion and excessive sediment yield. Population pressure leads to use of marginal lands and steep slope which could accelerate erosion processes.

Table 5: Annual soil erosion rates and severity classes in Chemoga watershed of the Blue Nile basin in the northwestern highlands.

Soil Loss (tha $^{-1}$y $^{-1}$)	Severity Classes	Area(ha)	Percentage of Total
<12	Low	4351.3	12.5
12-25	Moderate	4182.3	12.1
25-50	High	3731.3	10.8
50-80	Very High	2219.3	6.4
80-125	Severe	11650.4	33.6
>125	Very Severe	8552.2	24.7

Table 6: Rate of soil loss in Ethiopia.

Land Category	Soil Loss (t/ha/yr)
Crop land	42
Peren nial crops	8
Grazing and browsing	5
Currently unproductive	70
Currently uncultivable	5
Forest	1
Wood land	5

In the dry lands of Ethiopia, a combination of natural and human factors aggravates soil erosion. Additionally, the physical makeup of the highlands with gorges and other topographic barriers restricts the implementation of management and conservation practices. With increasing numbers of people, cultivation has expanded into ecologically fragile and marginal mountainous lands. Soil erosion therefore increases, and is a symptom of misuse and mismanagement.

Analysis of a compilation of soil loss rates due to sheet and rill erosion at plot and catchment scales indicates that this soil degradation process varies strongly spatially, with a mean soil loss 29.9 t ha $^{-1}$ yr $^{-1}$. The highest rates were observed in Anjeni (110 t ha $^{-1}$ yr $^{-1}$) and Chemoga (102 t ha $^{-1}$ yr $^{-1}$) of the Upper Blue Nile Basin. Studies in the northern Ethiopian highlands and the Central Rift Valley of Ethiopia reported larger erosive power of rainfall as compared to elsewhere in the world.

FAO (1986) estimated of gross annual soil loss nationwide of 1.9×10^{9} t of which 80% originates from croplands. Hurni (1988) estimated a nationwide annual gross soil loss of 1.5×10^{9} t, extrapolating data obtained from six SCRP research stations in which the highest loss is from croplands (42 t ha $^{-1}$ yr $^{-1}$). Tentative nationwide mean annual soil loss map combining the results of different model estimates [87]. They stated that soil loss varies remarkably from 0 t ha $^{-1}$ yr $^{-1}$ in the eastern and southeastern parts of Ethiopia to more than 100 t ha $^{-1}$ yr $^{-1}$ in the northwestern part of the country.

From the study conducted at different sites in the north Ethiopia shows that net soil losses from catchments ranges from about 3–49 t ha $^{-1}$ year $^{-1}$ with a mean value of 19 t ha $^{-1}$ year $^{-1}$. The relatively high soil-loss variability is due to the wide contrast in environmental variables of the catchments such as terrain, lithology, surface cover, and degree of gully erosion. The magnitude of annual soil loss observed in the study region is generally higher than the "tolerable" soil loss of about 2–18 t ha $^{-1}$ year $^{-1}$ estimated for Ethiopia. All the erosion estimates of the studied sites are above the minimum tolerable limit and five of the catchments have an annual soil loss above the maximum tolerable limit. The soil-loss rates are also beyond the rate of soil formation of 3–7 t ha $^{-1}$ year $^{-1}$. In addition, the mean net soil loss of 19 t ha $^{-1}$ year $^{-1}$ is high compared with the mean global (15 t ha $^{-1}$ year $^{-1}$) and mean African (9 t ha $^{-1}$ year $^{-1}$) sediment-yield rates.

In most findings conducted at Ethiopian watershed possibilities of high soil lose and risk was reported. Their findings revealed that the study areas are facing different problems such that forest transformation, which is very likely intensified by the demand for subsistence agricultural land. Most of the parts of these watersheds have experienced intensive soil erosion behavior, which is beyond the tolerable soil loss level. This threatens the annual crop production and the productivity of the land impacting the local farmers' food security. To deal with erosion, site-specific management measures are necessary.

Hence, review on identifying and prioritizing erosion susceptible areas for soil conservation measures are quite essential. Reviewing or quantifying the effects of the soil loss helps to substantiate investment in sustainable land management for the benefits to land users. Appropriate soil conservation measures bring economic advantages to the land users. Review on amount of soil loss and the status of the existing soil conservation measures can be realistic for farmers and policy makers if expressed in terms of understandable value.

RECOMMENDATIONS

For success of soil erosion risk prevention and soil and water conservation activities in the Ethiopian condition, the following recommendations should be considered as a best alternative and complementary actions.

- The developed model can be used in watersheds for erosion risk assessment, planning and subsequent prioritizations of conservation measures in erosion susceptible areas of the Ethiopian highlands. Review on amount of soil loss and the status of the existing soil conservation measures can be realistic for farmers and policy makers if expressed in terms of understandable value.
- Use of agronomic conservation measures: in densely populated areas of the country, where there is gentle slope up to 10% [88], farmers should use agronomic conservation practices to improve soil fertility, conserve soil moisture and then to reduce runoff. Contour cultivation, strip cropping, tree planting, manuring, mulching, and choice of appropriate cropping systems like intercropping and crop rotation are the major ones. These measures should be applied either alone or as complementary together with physical soil and water conservation measures based on slope profile and farming practices of the area.
- Complement physical soil and water conservation measures with biological stabilizers: the constructed mechanical soil and water conservation structures such as contour soil and stone bunding, bench terracing, fanya juu terracing, etc. Should be integrated and complemented with biological stabilizers. Integrating mechanical SWC with biological ones is instrumental for the sustainability of the structure and gives short term benefits to farmers.
- Complementing SWC measures with agricultural inputs: during implementing integrated soil and water conservation practices, inputs like improved seed, animal breed, fertilizer, fruit seedlings should be given to participants either on cash or credit basis. This gives opportunity to farmers to increase their crop yield and give sense of ownership to SWC structures.
- Consideration of policy issues on sustainable land management: policy issues on natural resource management such as people access to use and mange land, ownership structure of land, size of land, land use plan, social and economic objectives of land reform of the country should be considered in implementing sustainable and efficient SWC interventions. Furthermore, land-use plans should be practiced for the management and utilization of fragile and marginal areas. SWC should be implemented in integrated distributions based on participatory watershed management logic, starting from high erosion risk uphill areas and progressing down towards the watershed outlets.

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