

Extent of Gully Erosion and Farmer's Perception of Soil Erosion in Alalicha Watershed, Southern Ethiopia

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Abstract
A study was conducted to investigate the extent and rate of gully erosion in Alalicha watershed, southern Ethiopia. Gully measurements, field observations, and interviewing were used to generate the necessary data. Two sub watersheds; Bora and Banda were delineated and 21 gullies were identified. Investigation of the morphology, age and main causes for initiation of the gullies were carried out. The result shows that, long term gully erosion rate for the watershed was 2.12 t $ha^{-1}yr^{-1}$ and the total surface area occupied by gullies in Bora and Banda sub watersheds were about 19,328.2 m^2 and 6,433.2 m^2 respectively. The estimated total volume of soil loss was over 36,000 m^3 in Bora and 8,700 m^3 in Banda sub watersheds. A gully density of 11.1 m/ha for Bara and 6.7m/ha for Banda were estimated implying variations in severity of gully erosion. Based on length, all the gullies in the watershed have categorized under long gullies; however medium deep gullies dominate (77-88%) in both sub watersheds than shallow gullies (12-23%). Analysis of the gully morphology reveals that, a negative relationship exists between the top width and depth of gully. The damages and associated problems of the gullies, as explained by farmers, include loss of land, dissection of farms, and deposition of sediments on growing crops and restriction of movement of animal and people. The farmers of the watershed were well aware of soil erosion, soil fertility loss and erosion control and fertility management methods. However reluctant to implement as, they look food incentives because of poor economic status. Hence to conserve the land primarily awareness creation and encouraging the farmers through some sort of incentive may be required.
Keywords: gully erosion, gully morphology, farmers' perception and erosion control.

1. Introduction

Erosion, one of the symptoms of unsustainable land management, is an important degradation process affecting the soil resource in the entire world (Herweg and Stillhartd 1999). Erosion by water is the most serious form of land degradation process and accounts for 56% of the degraded soils in the world (Sohan and Lal, 2001; Elirehema, 2001). Erosion threatens our ability to sustain the growing population with food and fiber, and is closely linked to economic vitality, environmental quality, and human health concerns (Anthony and Lawrence, 2006). Roughly it is estimated that 75 billion tons of fertile topsoil is lost worldwide from agricultural systems every year (Pimentel, 2000) and nearly 10 million ha of cropland worldwide is abandoned every year because of problems associated with soil erosion alone (Pimentel, 2000).

The commonly recognized forms of water erosion are splash erosion, sheet erosion, rill erosion, gully erosion and stream bank erosion (FAO 1965; Dressing 2003), of which gully erosion is the alarming and appalling stage compared with sheet and rill erosion. Gully erosion is a highly visible form of soil erosion that affects soil productivity, restricts land use and can threaten roads, fences and buildings (Nyssen et al. 2004; Avni 2005; Carey 2006). It is the most prevalent type of water erosion in Ethiopia and it dissects the fields, impedes the tillage operations, damaging agriculture, residential area and restricts free movement of animals and human beings in different parts of the country (Daba et al. 2003; Woldeamlak and Sterk 2003; Awdenegest and Holden 2008).

Alalicha watershed, the study site, is one of the areas experiencing severe soil erosion and land degradation problems. To reverse the problems, several soil and water conservation interventions have been implemented for over a decade since 2000 by the government and community. However, in most parts, the control measures do not seem to be sustained and soil erosion is not controlled as desired, probably because of lack of good understanding and knowledge of the major gully erosion phenomenon in the watershed. The extent of gully erosion has not be quantified and the consequences identified and perhaps a major constraint for implementation of the correct conservation measure. Therefore, this study was designed with the aims; i) to evaluate the morphology and quantify gully erosion rate; and ii) to assess the farmers' perception on soil erosion and conservation practices. The investigation will provide a starting point to help develop a practical approach to soil erosion control interventions within the community that would have the greatest chance of success.

2. Materials and methods

2.1. Description of the study area

The study was conducted in Alalicha watershed Dale woreda, Sidama Zone of the Southern Nations Nationalities and Peoples Regional State (SNNPRS). It is found about 35km south east of regional city Hawassa along the main road from Hawassa to Yirgalem (Figure 1). Geographically, it is located between 06°49'11" - 06°47'05" latitude and 038°22'56" - 038°22'10"E longitude and its slope ranges from gentle to very steep slope (0-30 %). The watershed is composed of two sub watersheds Bora (286ha) and Banda (254ha). The rainfall pattern is bimodal and varies from 1000mm to 1666 mm and the mean annual temperature ranges from 18^{o}c to 25^{o}c. The farming system in the area is mixed agriculture and the dominant soil type is Nitosols.

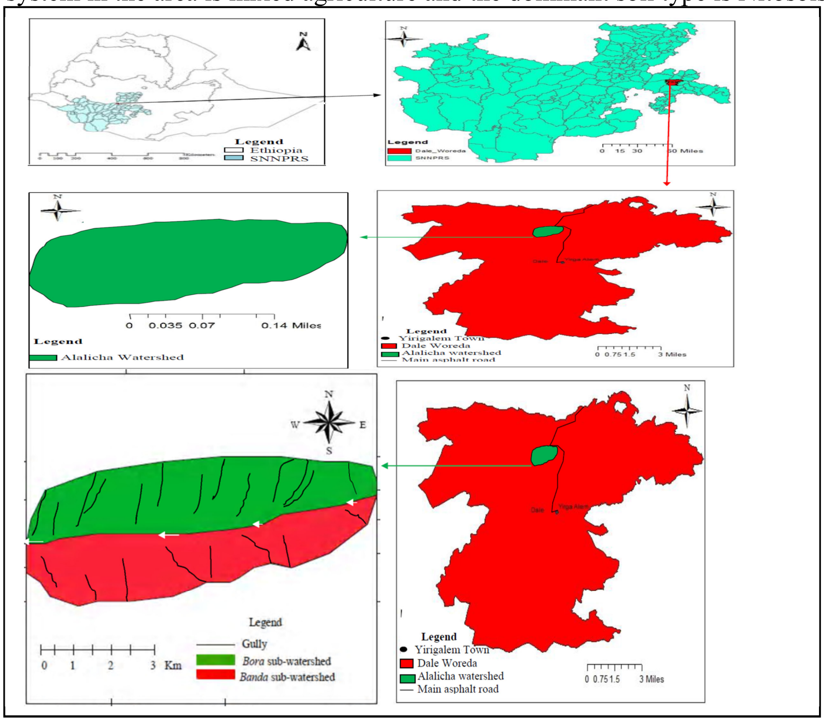

Figure 1: Location map of the study area

2.2. Measurements of gully morphology

Measurements of the gully dimensions were done after the gully length is dissected into sections of same cross- (Stocking and Murnaghan, 2000). Therefore, each gully section was measured for depth, width(s) and length, using measuring tape. In order to calculate the quantity of soil lost by gully, relationships and analysis has been done as follows.

A) Volume of soil lost (V) (m^3) = $\sum_{i=1}^{n} Vi$

Where; Vi = Volume soil lost in a section gully (product of gully cross sectional area to the gully section length).

B) Long -term gully erosion rate (RL) = $\frac{VBd}{TA}$

Where; V= Volume of soil lost (m3)
Bd = Bulk density of the soil (g/cm3).
T = age of the gully in years
A = Area of the sub-watershed in hectares.

C) Gully texture (gully surface area) in m^2 = Length (m) x Gully average top width (m)

D) Gully to plot area ratio = $\frac{\sum_{i=1}^{n} SAi}{A}$

Where; SAi = Surface area of unit gully (m^2).
A = Area of the sub-watershed (ha).
n = Number of gullies.

E) Gully density = $\frac{\sum_{i=1}^{n} \mathrm{Li}}{\mathrm{A}}$

Where; Li = Length of unit gully in meter
A = Area of the sub-watershed in hectares
n = Number of gullies

The evolution of the gully was studied in detail using the assessment of gully erosion rates through community interviews. To estimate the age of each of the studied gully, an event calendar (Table 1) was constructed through discussion held with key informants (KI). A total of seven key informants were selected from the village. Two were head of house hold whose land is found at the boundary of the gully, one development agent working in the area and four elder farmers who are knowledgeable about the area were selected. The researchers with the purposely selected key informants walked along each gully and discussed on the development as well as age of the gully.

Table 1: Event oriented calendar used in the questions

Year	Events	Description
2005	Election 97	Popular election held in May 15, 2005
1990	Downfall of the 'Derg' government	Movement that has brought the EPRDF to power
1988	Land reform	Land redistribution
1983	Extreme drought	Considerable part of the country as well people have been affected by the drought
1978	Country-wide repression (Key Shebir)	This was the response, massive killing of EPRP opposition party members by the 'Derg' government.
1975	Alphabetization campaign	Famous literacy champagne held throughout the country
1974	Downfall of Haile Selassie I	Movement that has brought the "Derg" to power

2.3. Farmers' perceptions on soil erosion and SWC practices

The perceptions of farmers on soil erosion and conservation practices were assessed using interviews. The questionnaire was pre-tested on 20 farmers before administrating on the sampled households. To obtain information about the same issues multiple methods (FGD and KII) were employed, to supplement the questionnaire results and to increase reliability of the data. In the watershed there are 277 households (HHs) and t 14 percent (40HH) of the total HHs was randomly selected for the interview and equally divided to Bora (20HH) and Banda (20HH) sub watershed. The random sampling was done using lists of all households which were obtained from the kebele administrations. Two FGD were carried out each with13 members of the community from both sub watershed. Three development agents of different disciplines (agronomy, soil and water conservation and animal production experts) working in the area were considered as key informants. The major issues covered include attitude of farmers on soil erosion and factors that constrain practicing soil and water conservation measures.

The distribution and frequency of the farmers' response were analysed using MS-Excel and the correlation between the volume of gully erosion as dependent variable and morphometric characteristics of gullies as independent variables was considered using stepwise method in SPSS version 16 software.

3. Result and discussion

3.1. The extent of gully erosion in the watershed

The longest gully was 427.4 meter while the shortest was 108 meters in both Bora and Banda sub watersheds. The main causes for the initiation and development of gullies were noted. Heavy rainfall was the primary reason identified as cause of gully. However, the most frequently mentioned man made causes were improper land development, construction of road, livestock and vehicle trails and unprotected feeder roads. The main asphalt road passes through the Bora watershed and runoff from road drainage has been found to contribute for the formation of two gullies in the Bora sub watershed. These gullies were the longest and severest gully recorded compared to others. Reports (Montgomory 1994; Wemple et al. 1996; Moyerson 2000) indicated that, inadequate drainage systems of roads such as small number of culverts and insufficient capacity of road ditches are some of the causes of gullying which is in agreement with the findings of the studied watersheds. A study on the highlands parts of Ethiopia (Solomon 2009) also reported that, construction of roads has a greater impact on the formation of gully formation and development than other factors.

3.2. Soil loss from gully and gully morphology

Total volume of soil lost from 13 recorded gullies in the Bora Sub watershed was 36,608.2 m^3 and the total surface area damaged was 19,328.2m^2. Similarly, in the Banda sub watershed the total volume of soil removed from 8 recorded gullies was 8,767.5 m^3 and the total surface area was 6,433.2 m^2. In comparison Bora sub watershed is highly affected than the Banda sub watershed (Table 2)

Table 2: Summary of Gully characteristics in the watershed

Gully characteristics	Bora Sub watershed	Banda Sub watershed	Mean	Std. Deviation
No. Gullies	13	8	-	-
Total length (m)	3151.0	1688.3	2419.7	+ 1034.3
Gully texture or total Surface area (m^2)	19,328.2	6,433.2	12880.7	+ 9118.2
Volume (m^3)	36,608.2	8,767.5	22687.9	+ 19686.4
Average depth (m)	1.8	1.5	1.7	+ 0.2
Average width at lip (m)	5.1	3.7	4.4	+ 0.96
Gully to plot area ratio	0.007	0.003	0.005	+ 0.003
Gully density (m/ha)	11.1	6.7	8.9	+ 3.1

Gully length: In Bora sub watershed, the longest and the shortest gullies were 427.4 meters and 108 meters respectively with the mean of 242.4 meter and standard deviation of + 95.1. On the other hand, the longest and the shortest gully in Banda sub watershed were 259 meter and 143 meters respectively with the mean of 211.1 meter and standard deviation of +42.2. The mean values of both sub watersheds indicate that, the average length of gully in Bora sub watershed is greater than that of Banda sub watershed. This variation on gully length might be due to presence of more gullies and relatively longer and steep slope in Bora Sub watershed.

Gully width and depth: As indicated in table 2, the mean value of gully top width was estimated to be 4.4 m with the standard deviation of + 0.96. This shows that the gullies in the area do not have wide variation in their width. Similarly, the average gully depth was 1.7 m with 1.8m in Banda and 1.5m in Bora sub-watersheds) indicating little variation in depth between sub-watershed compared to width of gullies. The variation on gully depth might be because of the depth of the soil and the slope variations in the watershed.

Gully texture and gully to plot area ratio: The total surface area occupied by gullies in Bora and Banda Sub watershed showed big variation, 19,328.2m^2 and 6,433.2 m^2 respectively. In total 25,761.4 m^2 area is damaged and these gullies dissected the filed in 21 places. As shown in table 2 above, the total damaged area in Bora sub watershed is three times larger than Banda sub watershed. Measure of gully to plot area ratio on Bora and Banda sub watershed were found to be 0.007 and 0.003 respectively with their mean of 0.005 and standard deviation of +0.003 (Table 2). This shows that for every 1000 units of land on Bora sub watershed, there were about 7 unit area of land were damaged. On Banda Sub watershed for every 1000 units of land, 3 unit areas of land were damaged. Such ratio tells the extent of area damaged and out of production. Girum (2007) indicated that, gully to plot area ratio in Kilie catchment, Lume woreda was 0.136 or 150 m/ha, which are out of production. Similarly Abiy (2008) reported that Kelala Dalacha enclosure in the central rift valley of Ethiopia had gully- plot area ratio of 0.0027, which much below than other reports as well as findings of this study. Therefore damaged area by gullies is not proportionate to the area under investigation but on the severity of erosion that is associated with the peculiar nature of a study area.

Gully density: As shown in table 2, the gully density of 11.1 m/ha was recorded in the Bora sub watershed, and 6.7 m/ha was in Banda Sub watershed. Which implies that, in the Bora sub watersheds was severely degraded than Banda, as gully density between 1000-2500m/100ha (10-25m/ha) is categorized as severely degraded. The Banda sub watersheds could be categorized as moderate to severe degraded area as gully density is estimated between 500-1000m/100ha (5-10m/ha). This variation on gully density with in sub watersheds might be because of the more number of gullies and coverage of greater surface area in Bora Sub watershed. However both could be classified as moderate to severe degraded. Similar result was found in central high land (Solomon 2009; Girum 2007), in central rift valley (Abiy 2008), and in southern high lands of Ethiopia (Anteneh 2009).

Gully volume: The total amount of soil removed from the gullies inside the Bora sub watershed was 36,608.23

m^3 (Table 2) and the average amount of soil removed from each gully was 2816.02m^3 with standard deviation of +4710.5. Similarly, the total amount of soil removed from the Banda sub watershed was 8,767.53 m^3 and the average amount of soil removed from each gully was 1095.95 m^3 with standard deviation of +745.6. Therefore, the total volume of soil lost from all gullies in the watershed (Table 2) is 45,375.76 m^3.

Gully category: Based on gully depth gullies were classified as small gully (less than 1m), medium gully (between 1-5 m) and large gully (greater than 5m) (Pathak et al 2006). In terms of gully depth measurement, there were 12 and 23% short gullies and medium gullies account to 88 and 77% in Banda and Bora sub watersheds respectively. There were no large gullies available in both sub watersheds.

Based on gully length, gullies were classified in to three categories small (<5 m), medium (5-10 m) and large gullies (>10 m) (Pathak et al. 2006; Sargeant 1984). The shortest gully length measured in the watershed was 108 meters, which is almost nine times greater than the longest gully reported by Pathak et al. (2006).

Based on gully continuation all gullies in the watershed are discontinuous and their depth increases from the up-stream to its mid-point and then decreases gradually. Perhaps this is because of the highly erodible nature of the soil at the middle section. The gullies studied on both sites have differing morphology along their lengths. Referring to the shape of gully cross section; those formed due to road drainage are V- shaped, deep and wide but seem to be stable at the upstream section. The mid sections of these gullies are U-shaped with steep sided walls and are very wide, with active erosion cave-in and tension cracking taking place. There are gullies that no more grow in length due to reaching the upper most of the catchment- catchment divide. On the other hand, gullies formed due to human and animal track and fed by runoff from roads have typically U- shape. These grow upstream and widen in its mid section. The lower parts of all gullies are trapezoidal in shape and stable. This result is similar with the findings of Solomon (2009) in central high land, Anteneh (2009) in Halaba woreda southern Ethiopia and Tigist (2009) near Lake Tana, northern highlands of Ethiopia.

3.3. Relationship between morphometric parameters of studied gullies

The correlation among the gully morphology (Table 3) shows that, there is a linear and positive relationship between width and length of the gully. Their relation is significant at 1% significance level with R^2 of 0.6. This relationship implies that with increasing one unit in the gully length, 0.6 unit of gully width will be increased. In other words, if the length of the gully is longer, its width is wider compared to short length gullies and the risk of land lost due to gully will be two fold in longer gullies. The reason for this may be when the runoff goes a long distance; it will get a chance to collapse the side of gully and may widen the sections as well. On the other hand, the statistic correlation (Table 3) showed negative relationship between top width and depth of the gully. Along the gully length, depth decreases with increasing in width of the gully although their R^2 value is - 0.15. Statically gully depth has no relationship with gully length because; the correlation value R^2 is 0.06 and non significant. The finding of Solomon (2009) shows similar evidence, the absence of relationship between gully depth and length at correlation value (R^2) of 0.26 in his study area. However, this research revealed that a linear and positive relationship exists between the W/D ratio and length of gully erosion.

On the other hand, the volume of gully had positive relationship with the length, top width and depth (Table 3). The volume of gully had a significant correlation with the length of the gully at P<0.01 with R^2 of 0.6.

Table 3: correlations among gully morphology

		Length	Width	Depth	Volume
Length	Pearson Correlation	1	0.600**	0.061	0.569**
Width	Pearson Correlation	0.600**	1	-0.15	0.303
Depth	Pearson Correlation	0.061	-0.15	1	0.072
Volume	Pearson Correlation	0.569**	0.303	.072	1

**.Correlation is significant at 0.01 level (2-tailed).

The simplest linear equation existed between the volume of soil loss indicated that more variation among the gullies which could be attributed to the variation in the length of the gullies. In addition to gully length, gully width had also closely related to gully depth, but the relationship, (R^2) but not significantly at P>0.05 (Table 4). The finding of this study showed that, the simple linear equation between the volume of the gully and other gully parameters will include only length and width of the gully.

3.4. The rate of gully erosion and its impact in the watershed

The total length of all gullies in the watershed is 4839.33 m, with a total volume of 45,375.76 m^3 and

Table 4: Volumes of gully and its morphometric characteristics

	R^2	P
V = 0.988L - 3.59	0.32	0.007
V = 0.927L - 0.868W- 3.66	0.33	0.03
V = 0.781L – 0.521W+ 0.121D -3.71	0.33	0.07

According to information obtained with the semi-structured interview the approximate incision period of the gully segments ranged from 15 years for the new gullies to 60 years for the old gullies. The mean value of the bulk density of the area was 1.12 g cm^{-3} and long-term gully erosion rate was calculated as 2.12 t ha^{-1} yr^{-1} since the incision period from 1952 to 2012.

Out of the total area of the watershed, 25761.4 m^2 of land is occupied by gullies dissects and some gullies have up to 6.6 meter depth and 27.5 meters width. Restricting free movement of animals and human beings has been raised as the major impact of the these gullies by the farmers.

3.5. Farmers' perception on soil erosion and soil fertility loss

Majority of the households (92.5 percent) of respondents in the watershed perceived the occurrence of soil erosion and see it as a problem on their farm land. They also believe the severity of the problem had increased in recent years. They also use various easily observable soil erosion indicators. The farmers' principal indicators of soil erosion were; decline in land productivity (yield) (92%), followed by requiring by fertilizers (88%), compactness of the soil (soil coarse) (86%); removal of top soil by runoff (78%); formation of rills (68%); decrease in soil depth (15%) and deposition of sediments (8%) (Figure 2).

Similarly, the above indicators were also obtained in other the studies, Abera (2003) in north western Ethiopia, Awdenegest and Holden (2007) and Mesfin (2011) in southern Ethiopia and Ouma and Sterk (2005) in Kenya.

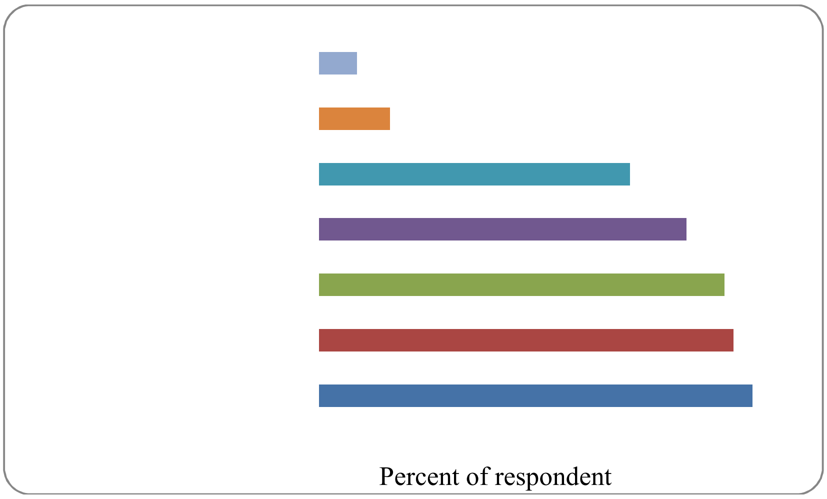

Figure 2: Soil erosion indicators by farmers

Ninety three percent (93%) of the sample households perceived the fertility decline of their cultivated land and of which the majority of the respondents also witnessed that they observed an increasing trend in the severity of fertility decline over the past 10 years. On the other hand, in the study watershed the farmers' are able to identify principal indicators for soil fertility loss. The survey result show that, reduced in crop yield (90%), requiring of artificial fertilizers (88%), barren land or lack vegetation verge (63%) and presence of rills or gullies on their farms (30%) as the indicators for soil fertility loss. The main factors for decline of soil fertility identified from the survey result were soil erosion, flowed by use of insufficient amount of fertilizer. Continuous cultivation and Poor soil management were also identified for the decline of soil fertility in the area. Like that, the major causes responded by respondents for soil erosion in the watershed is excess rain fall (78%), followed by lack of conservation structures (61%), Continuous cultivation (55%) and Poor soil management practice (19%).

3.6. Knowledge of farmers' on soil conservation and fertility management practices

The survey results show that, from 100% of farmers believe there are soil erosion and soil fertility loss on their farms. However 95% of them perceive the problems can be controlled. When asked to suggest actions and solutions to the problem of soil erosion, 85 per cent of farmers were able to suggest more than one action, which indicate that along with the knowledge of indicators and reasons for degradation, farmers also have knowledge of solutions (Table 5).

Table 5: Farmers' perception on soil erosion control and fertility management practices

Soil erosion controlling measures	Frequency	%	Soil fertility management practices	Frequency	%
Constructing terraces (buds and Fanya juu)	34	85.0	Use of chemical fertilizer	35	87.5
Contour ploughing	29	72.5	Use of manure	19	47.5
Cut -off –drain and Water way	14	35.0	Mulch or compost	5	12.5
Planting trees and agro-forestry practices	36	90.0	Agro forestry & Crop rotation	36	90.0
Different Check dam constructions	3	7.5	Controlling soil erosion	30	75.0

Farmers are aware of soil and water conservation practice and have knowledge on the benefits of soil conservation. Even though they have knowledge on soil water conservation practices, during the time of interviewing they have reported that the construction of soil conservation structures require high fund and labour. Under such circumstance individual farmers efforts do have limited capacity and government and non-government support in organising and funding the activities is required through various incentives programs like Food-For-Work (FFW). This is also supported during the group discussion that farmers have knowledge on SWC activities but for construction of structures on their land or on common land, they need to get some incentives. The reasons given included the food shortage and that it is proper to be paid for activities carried out in common lands. During the field visit it was observed that farmers' willingness to implement agro-forestry practices but reluctant to construct Physical SWC structures. There are similar finding in southern Ethiopia (Awdenegest and Holden 2007; Mesfin 2011) reporting that farmers do need some incentives to involve in soil conservation whether it is on their farm or in common lands.

4. Conclusions

The results obtained from measurement and observation showed that 21 gullies were formed between1952 to 2012 and the majority were developed between 1980 to1990. Gully density and plot to area ratio indicated that, the study area was considered as moderate to severely degraded area according to the classifications of gully density. Among the measured gully dimensions, length was found to be the most important parameter to estimate the volume of soil lost and the length of the gully had a positive correlation with width of the gully. The long term gully erosion rate for the area was 2.12 t ha^{-1} yr^{-1} and compared with other findings in Ethiopia of similar biophysical conditions this was low (Nyssen et al. 2004; Daba et al. 2003; Awdenegest and Holden 2008). However in terms of surface area coverage the impact has been found to be sever.

The sampled household farmers in Alalicha watershed are well aware of the problem of soil erosion and believed the severity of the problem had increased in recent years. In addition, most of the farmers suggested soil erosion as the major cause for soil fertility decline. But the little effort so far accounts for farmers are looking for incentives (food or cash) from the government or other NGOs. Based on the results of the study, we recommend that an appropriate soil and water conservation measure must be practiced to rehabilitate the gullies. Moreover there is a need to accompany this with frequent and appropriate maintenance of feeder roads, equally like that for newly construction main roads. Runoff generated along the road should be diverted to nearby natural water ways to minimize development of the gullies.

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References

Abera Birhanu. (2003). Factors Influencing the Adoption of Soil Conservation Practices in Northwestern Ethiopia. Discussion Papers No. 37. Institute of Rural Development, University of Goettingen, Germany.

Abiy Tsetargachew. (2008). Area Closure as a Strategy for Land Management: A Case Study at Kelala Dalacha enclosure in the Central Rift Valley of Ethiopia. Msc. Thesis, Environmental Science Programme, Addis Ababa University, Ethiopia.

Anteneh Getachew. (2009). Soil erosion assessment in agricultural landscape: the case of Rekame catchment, Alaba Woreda, Southern Ethiopia. MSc. thesis, Environmental Science Programme, Addis Ababa University, Ethiopia

Anthony, T.O., & Lawrence, J.S. (2006). Understanding Soil Erosion in Irrigated Agriculture. University of California, Division of Agriculture and Natural Resources, Publication, 8196. Natural Resources and Water,

State of Queensland.
Avni, Y. (2005). Gully incision as a key factor in desertification in an arid environment, the Negev highlands, Israel, Catena. 63: 185-220.
Awdenegest Moges & Holden, N.M. (2008). Estimating the rate and consequences of gully development, a case study of Umbulo catchment in southern Ethiopia. Land Degradation & Development. 19: 574-586
Awdenegest Moges and Holden, NM. (2007). Farmers' perceptions of soil erosion and soil fertility loss in Southern Ethiopia. Land Degradation & Development. 18: 543-553
Carey, B. (2006). Gully erosion. Department of Natural Resources and Water, State of Queensland. Available at: http://www.derm.qld.gov.au/factsheets/pdf/land/l81.pdf. Accessed on April 05, 2012.
Daba, S., Rieger, W., & Strauss, P. (2003). Assessment of gully erosion in eastern Ethiopia using photogrammetric techniques. Catena 50, 273- 291
Dressing, S. A. (2003). National Management Measures to Control Nonpoint Pollution from Agriculture-USEPA.
Elirehema, Y.S. (2001). Soil water erosion modelling in selected watersheds in south Spain.IFA, ITC, Enschede.
FAO. (1965). Soil erosion by water and some measures for its control on cultivated land. Food and Agriculture organization of the united nation, Italy Rome.
Girum Woldegiorgis. (2007). Assessment of Soil Quality and Erosion Rate in Kilie catchment, Lume Woreda, East Shoa, Ethiopia. MSc.Thesis Environmental Science Programme, Addis Ababa University, Addis Ababa, Ethiopia
Herweg, K., & Stillhardt, B. (1999). The Variability of Soil Erosion in the Highlands of Ethiopia and Eritrea. Research Report 42, Soil Conservation Research Program (SCRP), Centre for Development and Environment, University of Berne.
Mesfin Mentase. (2011). Assessing Factors Affecting Sustainability of Soil and Water Conservation Measures Based on Farmers' View at Wawarsa Watershed, Tembaro Woreda, Southern Ethiopia. Msc. Thesis, WGCFNR, Hawassa, Ethiopia.
Montgomery, D.R. (1994). Road Surface Drainage, Channel Initiation and Slope Instability. Water Resources Research. 30: 1925–1932
Moyerson, J. (2000). Desertification and Man in Africa. Bulletin of the Royal Academy of Overseas Science. Brussels 46:151–170.
Nyssen, J., Veyret Picot, M., Poesen, J., Moeyersons, J., Mitiku, H., Deckers, J., & Govers, J. (2004). The effectiveness of loose rock check dams for gully control in Tigray, northern Ethiopia. Soil Use and Management 20 (1): 55–64.
Ouma, B., & Sterk, G. (2005). Farmers' identification of erosion indicators and related erosion damage in the Central Highlands of Kenya. Kenya Agricultural Research Institute, Nairobi Kenya
Pathak, P., Wani, S.P., & Sudi, R. (2006). Gully control in SAT watersheds. ICRISAT. [On line] Available at http://www.icrisat.org/journal/agroecosystem/v2i1/v2i1gully.pdf; accessed on April 18, 2012.
Pimentel, D. (2000). Soil erosion and the threat to food security and the environment. Ecosystem Health 6:221–226.
Sargeant, I.J. (1984). Gully erosion in Vectoria. Proceeding of the Natural Soils Conference, May 13-18, Brisbane, Australia.
Sohan, W., & Lal, S. (2001). Extraction of parameters and modelling soil erosion using GIS in grid Environment, Paper presented in the 22nd Asian Conference on Remote Sensing 5-9 November 2001. Centre for Remote Imaging, Sensing and Processing (CRISP). Singapore.
Solomon Addisu. (2009). Assessment of the Impact of Road Construction on Physical Land Degradation in Central Highlands of Ethiopia: MSc Thesis in Environmental Science Programme, Addis Ababa University, Addis Ababa, Ethiopia
Stocking, M., & Murnaghan, N. (2000). Land degradation guidelines for field assessment. Overseas Development Group University of East Anglia, Norwich, UK.
Tigist Yazie. (2009). Assessment of hydrological controls on gully formation near lake Tana, northern highlands of Ethiopia. Msc. Thesis in Integrated watershed management and Hydrology at Cornell University.
Wemple, B.C., Jones, J.A., & Grant, G.E. (1996). Channel Network Extension by Logging Roads in two Basins, Western Cascades. Water Resources Bulletin 32 (6): 1195– 1207.
Woldamlak Bewket & Sterk, G. (2003). Assessment of soil erosion in cultivated fields using a survey methodology for rills in the Chemaga watershed, Ethiopia. Agriculture, Ecosystems and Environment 97 (1-3): 81 – 93.

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