A Participatory Assessment of Soil Erosion and Farm Management Practices in Northwest Ethiopia

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Abstract

Soil erosion is a widespread problem on cultivated fields in northwest Ethiopia. Plot level survey studies of soil erosion and conservation are few and far fewer have involved farmers in their assessments of the erosion process and farmers' conservation efforts. This paper presents the outcome of a farmer-participatory research conducted at two rural communities, Dubi and Gayta, in Dangila woreda (district), in the northwestern highlands of Ethiopia. The study estimated the extent of soil erosion from tree root exposure measurements and identified farmers' soil and water conservation (SWC) practices by categorizing the farmers into three income groups: poor, medium and rich households. Data were collected from 31 plots between May and October 2010. Descriptive statistics and analysis of variance (ANOVA) were used to analyze the data. The results indicate that average rates of soil erosion to be about 1.26 mm yr^{-1}, but rates varied from 1.94 mm yr^{-1} on seriously affected sites to 0.21 mm yr^{-1} on the relatively less affected areas. The farmers used contour farming, traditional ditches, grass and tree planting for SWC purposes. The study concludes that as the extent of soil erosion is highly variable spatially, plot and location specific SWC measures that are designed by considering farmers' indigenous knowledge will be required to control soil loss in the study area. This study demonstrates that participatory plot level tree root exposure assessment provides useful information for soil and water conservation planning.

Keywords: Soil erosion; Farmer participation; Tree root exposure; Conservation; Ethiopia.

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1. Introduction

In Ethiopia, agriculture is the main source of livelihood, employment, and foreign exchange earnings. It supports the livelihood of about 90% of the poor and generates 90% of the national export trade and greater than 40% of the Gross Domestic Product (Diao, 2010). But, the agricultural sector in Ethiopia is confronted with diverse environmental problems. Land degradation in the form of soil erosion causes a severe damage on crop lands, particularly in the highlands. The steep terrain, erosive rains, improper use of land and water, rapid population growth and dependence on fragmented subsistence farming are major causes of the ongoing land degradation (Gebreyesus and Kirubel, 2009). According to Constable (1984), some 1.9 billion tonnes of soil are removed each year from the Ethiopian highlands. Most of this loss was estimated to occur from cultivated fields where the soil rate was estimated at 100 t ha^{-1} yr^{-1}. Other studies have indicated much lower rates of soil loss. For instance, Woldeamlak and Sterk (2003) indicated soil loss rates ranging between 18-79 t ha^{-1} yr^{-1} from two micro-watersheds in northwestern highlands, and Nyssen *et al*. (2007) reported 57.3 t ha^{-1} yr^{-1} average sheet and rill erosion in Tigray, northern Ethiopia. All studies of soil erosion in Ethiopia, however, agree that the rate of soil erosion is high and constitutes an important problem to sustainable agriculture.

Even though soil erosion is a serious environmental and economic problem in Ethiopia, available studies on soil erosion measurement or estimation are quite few, and many are watershed or plot scales to ‘represent the diverse environments of the country’ (Woldeamlak and Sterk 2003). Herweg (1992) noted that the model of test plots is questionable, because they are confined to limited areas that might not represent wide spatial segments. Similarly, Stocking and Murnaghan (2001) state that experimental plots and quantitative models are ‘researcher-centered’ and vague to farmers in less developed countries to easily assess the level of erosion on farm plots. Woldeamlak and Sterk (2003) also note that plot and watershed level measurements do not show the extent of eroded soil from individual farm fields due to gaps in scale of measurement and applied methodologies.

Stocking and Murnaghan (2001) argue that participatory survey methodologies instead integrate local farmer experiences with scientific methods and provide opportunity for smallholders to easily estimate soil erosion from their farm plots and thus are 'farmer-centered' designs. Consideration of farmers' experiences, knowledge and views can provide essential inputs to the success of conservation interventions. The approach can even provide researchers the chance to learn from farmers how they realize and control soil erosion (Stocking and Murnaghan, 2001). For instance, Yifru and Taye (2011) have observed farmers classifying soils based on fertility and designing their farming practices using their indigenous know-how in southeastern Ethiopia. Similarly, Okoba and Sterk (2006) identified eleven erosion indicators through the use of farmers' indigenous knowledge and participation in Kenya.

One method of the participatory approaches is field survey of tree root exposures (Stocking and Murnaghan, 2001). Tree root exposure shows the removal of top soil covering the root part of a tree due to sheet or rill erosion. As trees are frequent and familiar biological features, the condition can be easily perceived and measured by farmers using simple tools like a ruler. This may also develop clear and practical awareness on the part of participant farmers. Tree root exposure measurements and computations do not require complex techniques and models. They are simple, cheap and flexible to explore with both semi-quantitative and qualitative methods. However, the methodology has some limitations. During tillage operations exposed roots are covered with soil and make identification difficult. Weed heaps collected at the base of some trees also make difficult to notice root exposures. Nevertheless, owing to the less cost and time required, the ease of measurements and computations, there is a possibility to consider it as one appropriate method to assess soil erosion. The aim of this paper was to assess the extent of soil erosion using tree root exposure measurements and examine farmers' SWC practices in the northwestern part of Ethiopia.

2. Materials and Methods

2.1. Site Description

The study was carried out in two Rural *Kebele* Adminstrations (RKAs, the lowest government levels in Ethiopia's administrative structure) named Gayta and Dubi in Dangila woreda (district), northwest Ethiopia (Figure 1). The two RKAs cover 2332 and

2358 ha, respectively, and experience slight differences in altitude and local climatic conditions. Slope gradients extend from < 1 to 50% in Gayta and to 45% in Dubi. The two RKAs are part of the northwestern highlands with elevations varying between 2100 m to 2300 m asl in Gayta and 1850 to 2255 m asl in Dubi. The local relief of both areas is broken by small streams and gullies that often fill with rainwater during the rainy season. The climate is moist *Weina-Dega (*sub-tropical) with a mean annual temperature of 17^0C and annual rainfall of 1578 mm as measured at Dangila town ($11^0$16'00"N and $36^0$50'00"E).

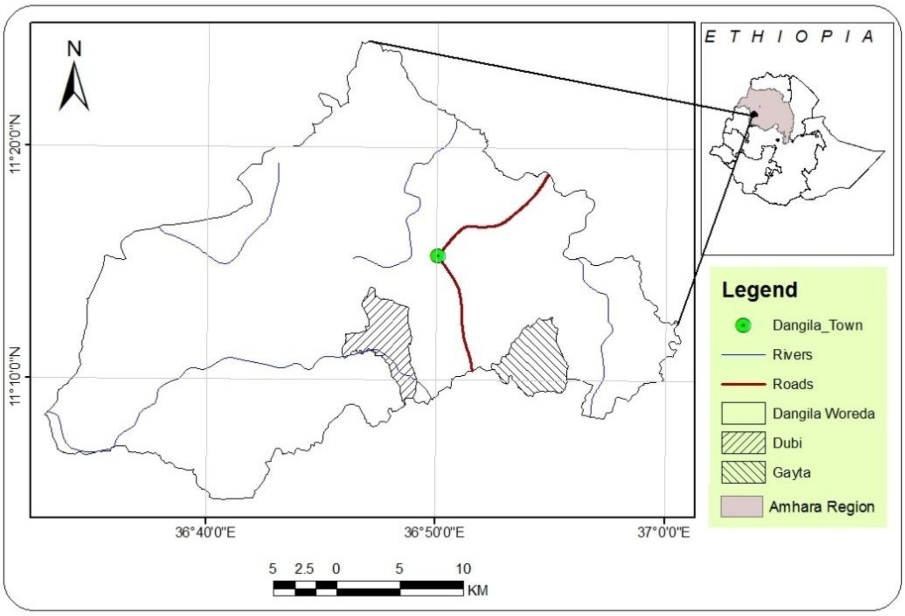

Figure 1. Location map of the study RKAs

Based on colour, the local people identify three soil types: *Forefor* (red colour), *Mezega* (black) and *Bunama* (grey-brown) as dominating the areas. The red soils (which belong to the Nitosols group) commonly occur on hilly and sloping parts in about half of both study sites. They exhibit a clay-loam texture and are most intensively cultivated but also most seriously eroded. The black soils (Vertisols group) are more prevalent in Dubi and often cover low lying landscapes. The grey-brown soils (Luvisols group) frequently occupy the pediments. Croton (*Croton macrostachyus*), Acacia (*Acacia lahai*), Eucalyptus (*Eucalyptus camaldulensis*), Cordia (*Cordia africana*), Albizia (*Albizia gummifera*), Terminalia (*Terminalia brownie*) and Justicia (*Justicia schimperiana*) form the dominant vegetation types in the areas. Crop-livestock mixed subsistence farming is the basic source of livelihood of the people in both sites. Crops and community grazing fields occupy large areas while forests comprise small proportions. Tef (*Eragrostis tef*) in Gayta and maize

(*Zea mays*) in Dubi are leading crops in area coverage and quantity of output. Vegetables and fruits are important crops cultivated using traditional irrigation around homesteads.

2.2. Data and Methods

2.2.1. Study framework

Erosion assessment by measuring tree root exposures has been conducted by many researchers in different countries. To mention some, Dunne *et al.* (1979) used the method and estimated average soil erosion rates at 8 mm yr^{-1} on basement rocks and 14.7 mm yr^{-1} on the lava plateaus in Kenya. Bodoque *et al*. (2005) applied the method in their study in Central Spain and estimated mean erosion rates at 1.7-2.6 mm yr^{-1} in one of their study sites (Senda Schmidt) and 1.1-1.8 mm yr^{-1} in another site (Monterrubio). They used dendro-chronological analysis to determine the age of the trees they used as references. But, Stocking and Murnaghan (2001) noted that tree-ring dating is not usually accurate because tree-rings are not annually created all the time, particularly in the tropics and subtropics. Trails and trekking grounds were main focus areas of Bodoque *et al*. (2005) study, while grazing fields were the focus areas of the study by Dunne *et al*. (1979). This study differs from these two studies in that it focuses on farm plots and it involved farmers in the survey process. Also, the ages of measured trees were determined by consulting the owners who have planted them. Thus, it was designed based on the ‘farmer-perspective’ model suggested in Stocking and Murnaghan (2001). The approach involved farmer participation in identification, measurement, mapping and ranking of affected areas. The steps of the participatory assessment process in general follow the sequence shown in Figure 2 below.

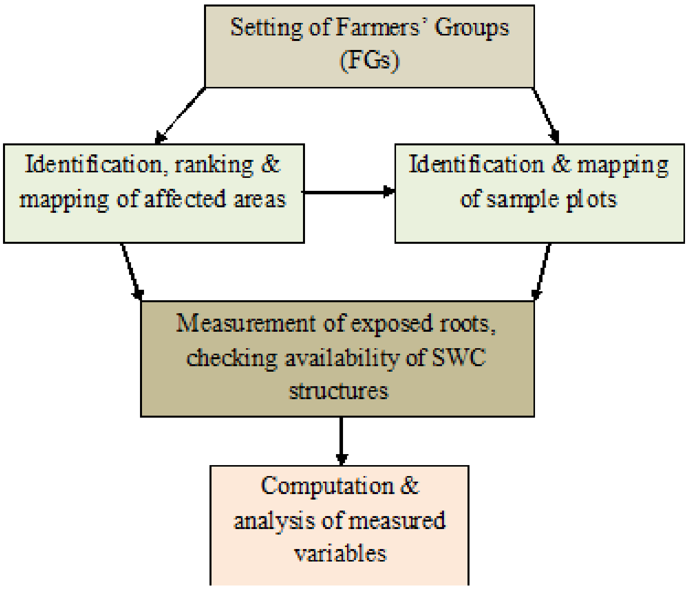

Figure 2. The participatory assessment process

2.2.2. Procedures of sample determination

The study was based on participatory field observation, formal and informal discussions with the local farmers and plot level field measurements. For this, first two Farmers' Groups (FGs), each containing six members, were set up in each study RKA. These FGs discussed, with facilitation by the lead author, on the problems of soil erosion and SWC practices and identified four villages in their respective RKAs as severely affected, moderately affected, slightly affected and non-affected areas, which were then ranked into four soil loss severity classes (Table 1) and mapped by the FGs and the researcher (Figure 3). For each site, presence of tree root exposures, gullies, rock-outcrops, soil colour and soil depth were assessed by a joint transect walk of the researcher and FG members.

Table 1. Estimated area, soil type and erosion severity rank of the eight villages in the two study areas

RKAs & Villages	Area (ha)	Major Soil type (colour)	Average soil depth (cm)	Soil texture	Erosion severity rank
Gayta					
Ashina	415	Red	55	Coarse	2
Giorgis	672	Brown	113	Loamy	3
Gishen	623	Light red	29	Very coarse	1
Selassie	622	Black	154+	clayey	4
Dubi					
Village One	541	Black	166+	clayey	4
Village Two	466	Red	58	Coarse	2
Village Three	901	Light red	27	Very coarse	1
Village Four	450	Brown	103	Loamy	3

Soil depth was measured from gully cuts and by digging using local tools. Soil texture was determined by finger-feel method in situ. The four soil erosion severity classes are the following:

i) Seriously affected: steeplands dominated by light-red sandy soils, affected by deep and wide gullies, exposed tree roots and rock outcrops. The soil depth is less than 50 cm.

ii) Moderately affected: steeplands, dominantly covered with reddish soils locally named *forefor*. The area contains gullies and soil depth is 50-100 cm.

iii) Slightly affected: gently sloping lands where soil erosion is low. The major soil is grey-brown having a depth of 100-150 cm.

iv) Non-affected: level lands where soil erosion is very low. The soil is much deeper and dominantly black in colour. Gullies are more or less absent; no concentrated water flow except in the perennial large gullies crossing community grazing fields originating from highly degraded upslope areas.

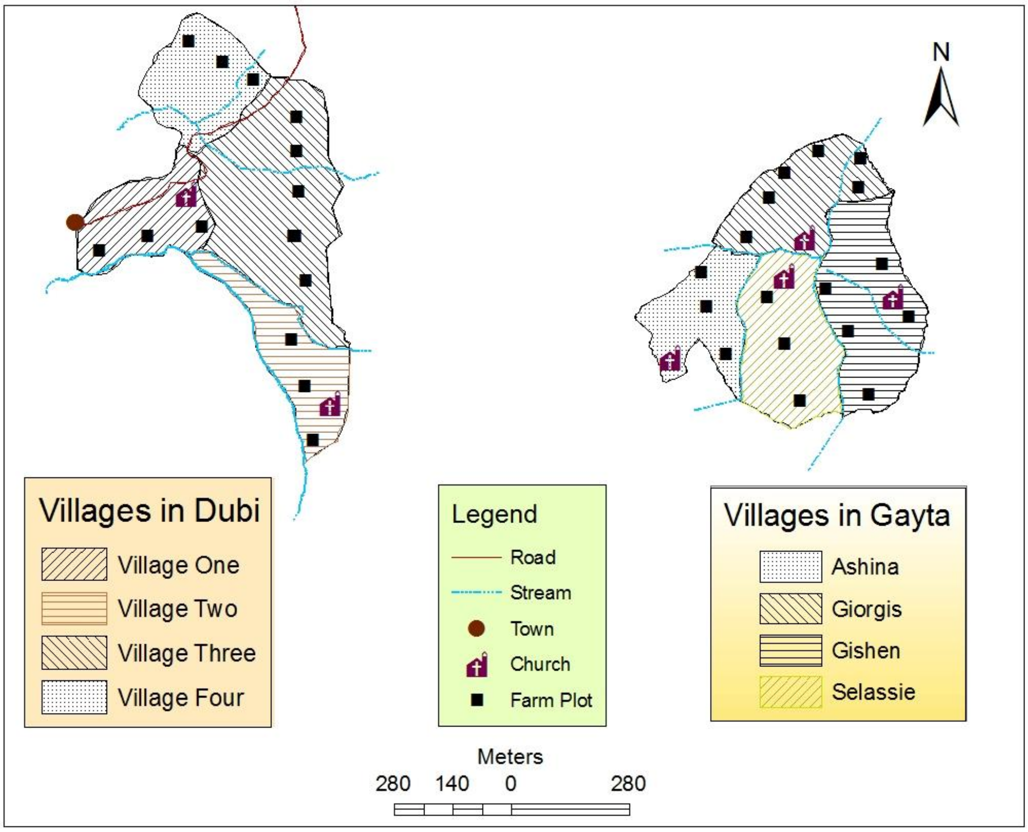

Figure 3. Sketch map prepared by FGs and the researcher, May 2010.

Following mapping and ranking, 31 plots (17 in Gayta and 14 in Dubi) were selected on purpose to represent three broadly defined household income (wealth) groups (HIGs), namely poor, medium and rich households as stratified by the FGs by using landholding sizes, oxen ownership and annual food production[3]. Based on this, 22 plots were from the poor and medium farmers (11 from each) and the rest (9 plots) were from the rich farmers (Table 2).

Table 2. Number of assessed farms and measured trees by village and HIGs*

Study sites	N^0 of assessed farms				N^0 of measured trees			
& villages	P	M	R	T	P	M	R	T
Gayta								
Ashina	1	1	1	3	3	2	3	8
Giorgis	2	2	2	6	5	7	7	19
Gishen	2	2	1	5	5	8	2	15
Selassie	1	1	1	3	5	4	3	12
Dubi								
Village One	1	1	1	3	5	5	3	13
Village Two	1	1	1	3	3	5	4	12
Village Three	2	2	1	5	8	6	5	19
Village Four	1	1	1	3	3	5	2	10
Total	11	11	9	31	37	42	29	108

*Refers to P: Poor, M: Medium, R: Rich, T: Total

2.2.3. Data acquisition

Assessment of tree root exposures was conducted in the presence of plot owners and FGs. A detailed observation of the surrounding biophysical environment of the farms was made before measurement of exposed roots. The size of sampled fields and age of the target trees were first recorded by consulting plot holders. Local slope gradients were determined using clinometers. Soil types and their depths, and availability of any erosion control practices were recorded through observation and field measurements.

Next to recording of the surrounding geographical features, a close observation was made on tree root morphology to detect any changes in color, texture and structure of the tree stem based on methods cited in Dunne *et al.* (1979). Then heights (length from the upper part of the root to the present ground level) of exposed roots were measured using ruler

[3]Poor: households owning <1 ha of land, do not own any or have only one ox and do not produce sufficient food for themselves annually. Medium: households who own 1-2 ha of land, two or three oxen and produce sufficient food for one year. Rich: households with >2 ha of land, own more than three oxen and produce surplus annually.

following methods suggested in Stocking and Murnaghan (2001). Based on the measurements, data were gathered from 108 trees of different species, namely, croton (*Croton macrostachyus*), acacia (*Acacia lahai*), eucalyptus (*Eucalyptus camaldulensis*), albizia (*Albizia gummifera*), terminalia (*Terminalia brownie*) and sesbania (*Sesbania sesban*) from May to October 2010. The minimum number of trees observed per plot was two and the maximum was five. On average, about three trees far apart at least 8 to 10 meters were assessed from each plot. The size of each measured plot was about 0.25 ha. Of the total 108 measured trees, 37, 42 and 29 belonged to poor, medium and rich households, respectively (Table 2).

2.2.4. Data analysis

Average rates of annual soil loss were computed for each tree by dividing the measured exposed root height to its respective age as suggested by Stocking and Murnaghan (2001). This has provided the estimate of lost soil in terms of millimeters per annum for each measured tree. Average erosion rate for all trees was then calculated by adding the values of all measured trees and dividing the sum to their total number. A one-way ANOVA was employed to examine the mean difference in erosion, root exposure and tree age among the 31 farm plots. A two-way ANOVA was used to see the mean difference in soil loss among the study sites, slope categories, soil types and farm fields of the different HIGs.

3. Results and Discussion

3.1. Erosion Assessment

Table 3 presents summary statistics about tree age, root exposure and soil loss for the measured farms. Average exposed root height and mean tree age were 20.7 mm and 16.6 years, respectively. Exposed root height ranged from 2 mm to 61 mm, while tree age varied between 3 and 38 years. From these measurements, on average 1.26 mm of soil depth or 16 tonnes of soil per hectare has been lost annually (Table 4). This rate is less than the maximum tolerable erosion (which is 18 t ha^{-1} yr^{-1}) but over the minimum rate (i.e. 2 t ha^{-1} yr^{-1}) cited in Gebreyesus and Kirubel (2009). The figure is much higher if compared to the 6 t ha^{-1} yr^{-1} tolerance erosion rate predicted by Hurni (1983) for areas located 2000-2500 m asl in the Simen Mountains of Ethiopia. Conversely, it is much lower when compared with the average erosion rates estimated in northwest Ethiopia, 18-79 t ha^{-1} yr^{-1} in Woldeamlak and Sterk (2003) and 93 t ha^{-1} yr^{-1} in Woldeamlak and Ermias

(2009) in the Chemoga watershed as well as 27 t ha^{-1} yr^{-1} in Tibebu *et al*. (2010) near Lake Tana. But, it can be taken as modest in the context of a moderate erosion rate of 16-50 t ha^{-1} yr^{-1} mentioned in Lakew *et al*. (2000) for the western zones of Amhara region, Ethiopia. Soil loss rates ranged from 0.12 mm to 2.8 mm yr^{-1} and significantly differed across the measured fields as shown by the results of the one-way ANOVA (Table 3).

Table 3. Summary statistics of tree age, root exposure and soil loss

	Variables		
Statistics	Tree age (years)	Root exposure (mm)	Soil loss (mm yr^{-1})
N	108	108	108
Mean	16.56	20.72	1.26
Standard deviation	6.71	14.59	0.71
Minimum	3.00	2.00	0.12
Maximum	38.00	61.00	2.80
Coefficient of variation	0.41	0.70	0.57
F	2.37	3.56	6.71
P	0.001	0.000	0.000

Murnaghan (2001) considering a bulk density of 1.3 for recently cultivated tropical soils mentioned in Fitzpatrick (1992).

Table 4. Rates of soil erosion by study site and village

RKAs &	Mean		SD	Range
Villages	mm yr^{-1}	(t ha^{-1} yr^{-1})^{a}	mm yr^{-1}	mm yr^{-1}
Gayta				
Giorgis	1.1	14	0.41015	0.57-1.93
Ashina	1.52	20	0.23245	1.15-1.83
Gishen	1.51	20	0.36353	0.83-1.94
Selassie	0.55	7	0.36472	0.13-1.25
Total	1.15	15	0.51448	0.13-1.94
Dubi				
Village One	0.21	3	0.08348	0.12-0.43
Village Two	1.94	25	0.66832	0.77-2.80
Village Three	1.72	22	0.69851	0.50-2.71
Village Four	1.51	20	0.45639	0.67-2.14
Total	1.37	18	0.86240	0.12-2.80
Grand total	1.26	16	0.71498	0.12-2.80

[a]mm yr^{-1} values converted to t ha^{-1} yr^{-1} based on 1 mm ~13 t ha^{-1} suggested in Stocking

Bodoque *et al*. (2005) estimated mean annual soil loss rate as ranging between 1.1 to 2.6 mm in their study in Central Spain. These rates are almost nearer to the rates recorded in this research (0.12-2.80 mm yr^{-1}). The slight differences may be caused by variations in local climate, geographic location and the methodology used. Ethiopia is a tropical country while Spain is in the temperate zone. Trail was the base of measurement in Bodoque *et al*. (2005) and they used ring dating methods while this study relied on recording age of trees by consulting tree owners on farm plots. Natural erosion rates (1.24-1.90 mm yr^{-1}) cited in Krusic (1990) for the Hiking trails, New Hampshire (USA), is not much far from the findings of this research. But, their trail erosion rates ranging 6.6-7.5 mm yr^{-1} is much greater from the natural rate cited in their paper and from the results recorded in this paper. Such variations are expected because the natural rates are resulted from purely natural geological factors and the rates cited in this paper are initiated by tillage erosion and also natural factors.

3.1.1. Soil erosion variations across the study sites

Villages Two, Three and Four in Dubi RKA, and Ashina and Gishen in Gayta RKA face the largest soil removals (Table 4). These villages all lie on degraded parts of the two communities. They are dominated by shallow red soils and steep slopes. The highest erosion rates occurred in areas characterized by steep topography, and coarse and shallow soils. The lowest erosion rates were observed as expected in what were classified by the FGs as non-affected villages (village One in Dubi and Selassie in Gayta). The results in general indicate that soil erosion differs at micro-levels. Results of the two-way ANOVA (Table 5) show significant mean erosion difference across the villages at $p < 0.001$.

Table 5. Results of the two-way ANOVA

Grouping variables	Soil loss (mm yr^{-1})		Exposed root length (mm)	
	F	Sig.	F	Sig.
Study site	0.001	0.973	7.37	0.008
Slope	32.88	0.000	14.17	0.000
Interactions	4.77	0.010	1.09	0.340
Study site	1.15	0.287	1.72	0.192
Soil type	8.25	0.000	7.38	0.001
Interactions	7.83	0.001	7.51	0.001
Village	21.99	0.000	9.042	0.000
HIGs	0.242	0.786	0.340	0.713
Interactions	2.099	0.020	1.544	0.113
Slope	36.6	0.000	11.24	0.000
HIGs	0.254	0.776	0.301	0.740
Interactions	0.223	0.925	0.513	0.726

The variations are expected as the villages differ in slope gradient, soil type and overall extent of land degradation and the results matched with the ranks given by the FGs (Table 1).

3.1.2. Soil loss variations by slope and soil type

Table 6 summarizes the proportion of measured farms and soil removals at the various slope categories and soil types. The results of the two-way ANOVA (Table 5) indicate that there are significant soil loss differences among the three slope categories (at $P < 0.001$). Steep slope areas that comprised 36% of the measured farms faced the largest soil removal (52% of the total soil loss). In this area mean soil loss has been about 1.77 mm yr^{-1} (Table 7). Soils here are coarse textured and shallow in depth. Hence, slope and soil properties have contributed to the high rate of soil erosion by water. Average soil loss was moderate (about 1.2 mm yr^{-1}) on gently sloping mid-stream areas where 45% of measured farms are located. These areas accounted for about 35% of the total soil loss.

Table 6. Proportion of measured farms and soil loss by slope, soil type and HIGs

	Measured farms (%)			Total soil loss (%)		
Variables	Gayta	Dubi	Total	Gayta	Dubi	Total
Slope						
Plain	18	21	19	22	6	13
Gentle	59	29	45	34	38	35
Steep	23	50	36	44	56	52
Soil types						
Red	65	43	55	44	43	43
Black	12	21	16	36	15	23
Brown	23	36	29	20	42	34
HIGs						
poor	35.3	35.7	35.5	27	35	32
Medium	35.3	35.7	35.5	38	31	34
Rich	29.4	28.6	29.0	35	34	34

Table 7. Soil loss rates by slope, soil type and HIGs

	Mean		SD	Range
Variables	mm yr^{-1}	t ha^{-1} yr^{-1}	mm yr^{-1}	mm yr^{-1}
Slope				
Plain	0.44	6	0.43816	0.12-1.90
Gently sloping	1.20	16	0.53190	0.13-2.47
Steep	1.77	23	0.60329	0.50-2.80
Soil type/ depth				
Red/shallow	1.46	19	0.56556	0.13-2.80
Black/deep	0.80	10	0.58037	0.12-1.94
Brown/moderate	1.17	15	0.85004	0.13-2.75
HIGs				
Poor	1.19	15	0.82740	0.13-2.71
Medium	1.29	17	0.63780	0.12-2.75
Rich	1.30	17	0.68418	0.13-2.80

Erosion rates range from 1.7-36.4 t ha^{-1} yr^{-1} on red soil areas, 1.7-35.8 t ha^{-1} yr^{-1} over brown soils and 1.6-25.2 t ha^{-1} yr^{-1} at areas covered with black soils (Table 7). These results are by far very low compared to 17-176 t ha^{-1} yr^{-1} for red and 59-167 t ha^{-1} yr^{-1} for brown soils (luvisols) cited in Herweg and Ludi (1999) in Anjeni, northwest Ethiopia. The results for the black soils; however, indicate larger rates as compared to 0-16 t ha^{-1} yr^{-1} recorded at Hunde-Lafto, southeast Ethiopia (Herweg and Ludi, 1999). The reason for the mentioned differences may probably be the methodology applied, soil mineral and organic matter content and topographical and climatic variations of the research areas. It is obvious that this research was based on field survey while those cited in Herweg and Ludi (1999) were based on test plot experiment. With regard to soil type, higher mean erosion rates were recorded on farms with red soils where 55% of the total farms are found (Table 6). These soils are coarse and shallow occupying steep slopes. They are intensively cultivated for long time and are significantly affected by erosion. Black soils that make up 16% of the measured farms contributed to some 23% of the total soil loss. These soils face low erosion rates as they occur in level topography.

3.1.3. Soil loss variations by household income groups

Soil erosion rates were compared by the income status of the households cultivating the sample fields. It was found that in the plain areas, farms cultivated by the poor households suffered more than those cultivated by the other income groups. On gently sloping lands, both the poor and medium household farms faced large soil erosion rates of about 1.2 mm yr^{-1}. In the steep slopes, farms cultivated by the rich households suffered the most (Figure 4).

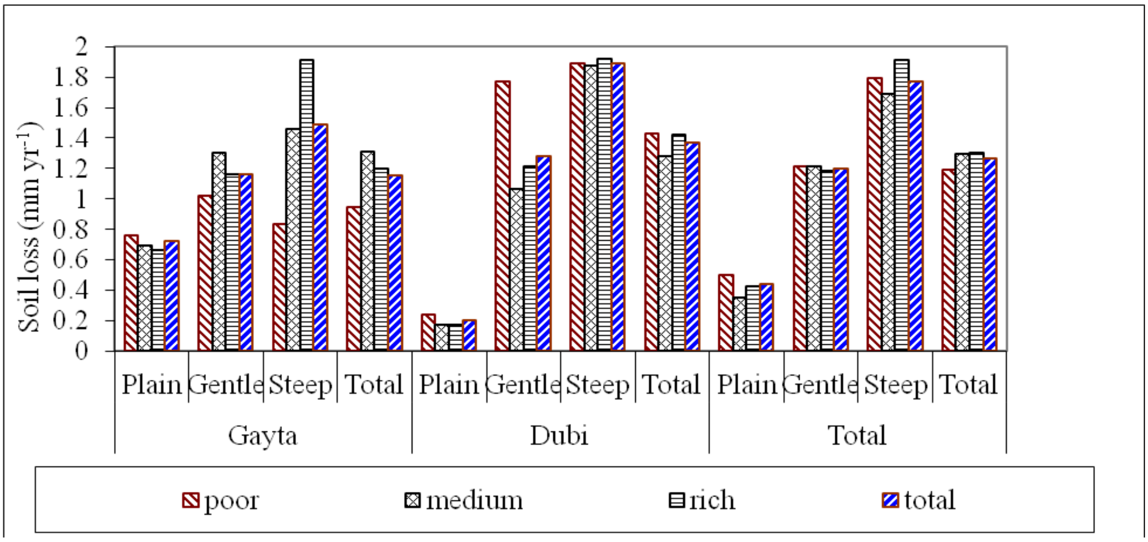

Figure 4. Soil loss on poor, medium and rich people farms by slope.

But, the results of the two-way ANVOA (Table 5) show statistically non-sgnificant differences in soil loss by the household income groups. Household income is thus not an important factor in determining soil erosion rates from individual farm plots.

3.2. Soil and Water Conservation Practices

Farmers in the study areas use different soil and water conservation measures. These include contour farming, terracing, check dams, water ways, cutoff drains, grass strips, and planting trees.

3.2.1. Contour ploughing

Contour ploughing is a very common traditional practice elsewhere in Ethiopia. It was expectedly used by all of the farmers sampled for this study (data not shown here). Ploughing is the practice of land preparation before sowing to make the soil more porous to water seepage, minimize weed emergence and improve land productivity (Yifru and Taye, 2011). In the study villages, farm lands are commonly tilled three to seven times depending on the requirement of the specific crop. Millet and maize fields are often ploughed three to five times while tef fields are tilled four to seven times. As Woldeamlak (2003) notes; however, repeated tillage and fine seed-bed formation prepares the soil to more erosion. Nyssen *et al*. (2000) remarked that traditional contour farming practices encourage gradual down-slope soil translocation and material accumulation in the lower farm margins. Therefore, there is the need to assess the benefits and adverse effects of the traditional practice of repeated tillage.

3.2.2. Terraces and bunds

Terraces and bunds were applied in 32% and 19% of all the farms, respectively (Table 8). In Dubi, 36% of the farms had soil terraces and 29% contained stone-bunds. The proportion of these SWC structures is less in Gayta compared to Dubi. Soil terraces were seen on 29% and stone-bunds on only 12% of the assessed farms in Gayta.

Table 8. Proportion of farms with SWC structures by study site (% of farms having SWC structures calculated for each site from all measured farms in each RKA).

SWC practice	Gayta	Dubi	Total
Soil terraces	29	36	32
Stone-bunds	12	29	19
Grass strips	41	36	39
Ditches/water ways	53	50	52
Cutoff drains	47	36	42
Trees	100	100	100
N^0 of farms	17	14	31

These SWC structures were generally applied on steep slope farms. They were first introduced to the area in the 1980's. Soil, stone, wood or a combination of both were used in construction of terraces and bunds (Figure 5). Both terraces and bunds are important to cultivate grass but they require large labor to build. Vancampenhout *et al*. (2006) for instance indicated spaces occupied by stone-bunds were used to grow fodder grasses in Tigray, northern Ethiopia. They are important measures in steep slope areas. But, farmers in the study villages complain that terraces and bunds take part of their plots and host pests that attack crops. Such complaints were also reported in Herweg (1992). But, Vancampenhout *et al*. (2006) reported that yields increased by 7% through application of stone-bunds and no yield reduction occurred due to 8% land occupied by stone-bunds.

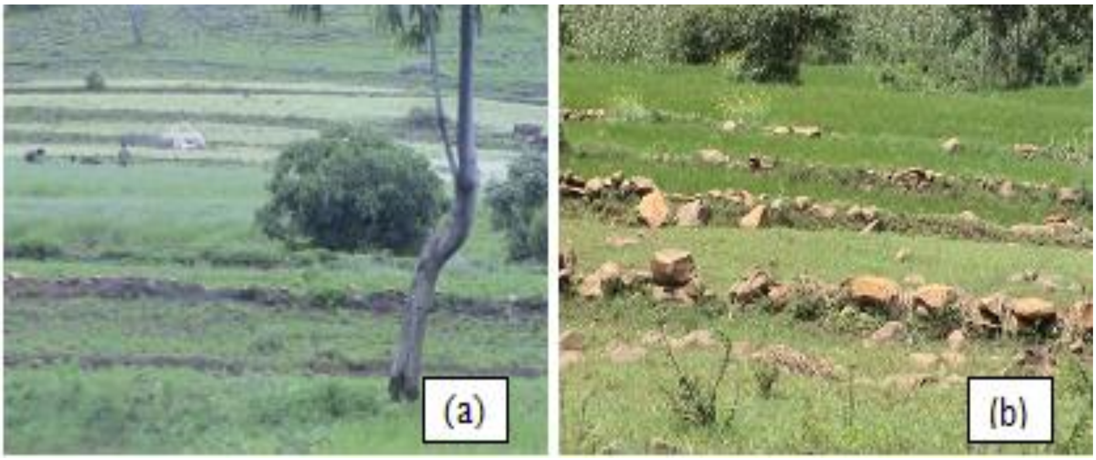

Figure 5. a) Soil terraces in Gishen (Gayta) and, b) stone-bunds in village three (Dubi), (Photo Sept. 2010)

3.2.3. Water ways and cutoff drains

Water ways (locally known as *feses*) are commonly constructed diagonally from the top to the bottom edge of a farm to drain out excess water. Cutoff drain, locally called *tiras boy* is however built horizontally at the head of farms to collect and channel upcoming runoff.

Water ways were observed in 53% of the farms in Gayta and in 50% farms in Dubi. Cutoff drains were observed in 47% of the farms in Gayta and in 36% of the fields in Dubi. Using water ways is common in level and water-lodged farms. In total, over 50% of the measured farms were observed having water ways, while cutoff drains were found in only 42% of the fields. As they are easy to construct using a plough during tillage operations, they are exercised by many farmers.

3.2.4. Grasses and Trees

Grasses and trees are planted to serve numerous purposes such as: control of soil erosion, source of animal feed, fuel and construction material. They are also sold in towns to generate income. Almost all of the measured farms contain trees and 39% of them contain grass strips (Table 8). Trees were found at the centers as well as at the margins of the fields. Grasses commonly occupied farm boundaries and planted on strips across the centers of few fields. Both grasses and trees were adopted by many farmers because they require less labor and provide diverse benefits. Grass and tree barriers in general deter the speed of running water and improve soil stability and sediment deposition.

4. Conclusions

The objective of this study was to assess the extent of soil erosion using tree root exposure measurements and examine farmers' SWC practices in the northwestern part of Ethiopia. The results show that the annual average rate of soil loss in the study area is about 16 tonnes per hectare or a soil depth equivalent of 1.26 mm. Soil loss rates significantly differed within farm fields, villages, soil types and slope categories (at $p < 0.001$). This implies that SWC and land management practices should be designed and implemented considering land slope, soil type and topographic location of farms. Each particular site thus requires specific SWC measure that fits its unique characteristics. Contour farming, ditch construction, grass and tree planting were observed most widely practiced SWC structures by the local farmers. Future SWC and land management should focus on integrated interventions that involve biological and structural measures and participation of land users.

The results obtained in this participatory research indicated that the 'farmer-perspective' framework is a good mechanism to estimate soil erosion rates on cultivated fields by simply measuring exposed roots. Since trees are familiar objects on farm plots farmers can easily and quickly measure exposed roots and assess the amount of soil removed by dividing the measured lengths to the tree ages. This farmer participatory research approach is thus practical, simple to implement in local contexts and help to reverse the long existing ‘scientist-to-farmer’ to a ‘farmer-to-farmer’ approach. The participatory survey methodology, therefore, can be taken as a good alternative to complex models to estimate soil erosion rates at the farm level, where other more reliable measurements are unavailable.

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