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Rill Erosion Assessment in Cultivated Lands and Farmers Perception on Soil Erosion, A Case of Delbo Wogene Micro-Watershed Southern Ethiopia

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Abstract
Land degradation in the form of soil erosion is a major constraint to farming activities and sustainable agricultural development in Ethiopia. Sophisticated methods of erosion measurements are expensive, time consuming and requiring highly trained manpower. However, simple field methods also could give adequate and reliable information such as field method of rill assessment. Most soil and water conservation planning approaches rely on empirical assessment methods and hardly consider farmers' knowledge of soil erosion processes. Therefore, this study was aimed at assessing the magnitude and rate of rill erosion and to evaluate the farmers' perception about erosion control practices, causes of soil erosion; constraints of soil and water conservation practices and identify local erosion indicators based on farmers' knowledge and assess relevance of these indicators in estimating soil erosion damage. The Delbo Wogene watershed in which the study conducted was located in Wolaita Zone, Southern Ethiopia. This study presents rill assessment through survey methodology and farmers' perception. Social survey data were assessed based on descriptive statistics. To quantify the amount of soil loss due to rill erosion, each rill's dimensions were carefully sectioned and measured to determine the volume and rates of soil erosion. The average total volume of soil loss due to rill erosion was 26.8m^3 which is equivalent to 27.8 t ha^{-1}. The average total rate of soil loss from both rill and inter-rill erosion in the study area was 35.75 t ha^{-1}. The mean total soil loss estimated using USLE resulted 48.6t ha^{-1} years from twelve cultivated fields at the upper, middle and lower zones of the study catchment. The HH survey results reveal that 73% of the farmers in the study catchment were aware of the problem of rill erosion feature and believed its severity. Lack of vegetation cover and excessive rainfalls were ranked first, 65% and 61% and 48% of respondents were ranked broken SWC for second as major causes of soil erosion respectively. The overall outcome from the research showed that unless appropriate interventions taken in the study area, reversing the soil erosion process would become difficult for the future. Based on the outcome, land management practices such as agro-forestry systems, conservation tillage, crop rotations and site-suitable SWC structures and crop rotations should be practiced in the study area with a full consensus and participation of the dwellers by giving attention to keep the standards of physical structures.
Keywords: Rill erosion, soil loss, Farmers perception, Erosion indicators, SWC, Delbo Wogene, Southern Ethiopia

1. INTRODUCTIN

1.1. Background of the study

In Ethiopia land degradation in the form of soil erosion and declining fertility is serious challenge to agricultural productivity and economic growth (Mulugeta, 2004). Soil erosion by water is by far the greatest land degradation problem. Water erosion not only removes nutrients but also may reduce thickness and the volume of water storage and root expansion zone. In Ethiopia the magnitude and rate of soil erosion continued to increase despite the considerable efforts made during the past three decades. The soil conservation research project estimated an average soil loss of 42t ha^{-1}year from cultivated lands and in highly erodible and intensively cereal cultivated fields May 300-400t ha^{-1}year soil loss is also reported (Daniel et al., 2001).

The problem of environmental deterioration has now become one of the most serious problems confronting mankind (Taffa, 2002). Among these problems, land degradation, caused due to natural phenomena and anthropogenic factors, was taking place in larger extent. Land is a complex and dynamic combination of factors: geology, topography, hydrology, soils, microclimates and communities of plants and animals that are continuously interacting under the influence of climate and of people's activities (Hudson, 1995). Land degradation is the most notable phenomenon in Ethiopia (Ermias *et al*., 2006). There are multiple interacting forces, which have caused and causing land degradation in Ethiopia (Berry, 2003). Soil erosion as one of land degradation components, has a negative impact on agricultural production, water quality and in general quality of life. Soil erosion is the process of detaching and transporting soil particles, which is caused by water or wind or both of them (Morgan, 1995).

In Ethiopian highlands farmers cultivate lands with slopes exceeding 60% (Gete, 2000; Girma et al.,

2002) and the existing land holding per household reduce from time to time and they are forced to cultivate marginal steep lands. Since the highlands are already over pressed, there is less opportunity for increasing area of land under agricultural production. As far as other alternative food sources are concerned, researches have been and still being conducted on these sources and it is still under investigation. So the only opportunity left for Ethiopian highlands (lands above 1500 m .a. s l) is increasing agricultural production per unit area.

Soil erosion is recognized as one of the world's most serious environmental problems (Pimentel et al., 1995, Shiferaw and Holden, 1999). Globally, about 80% of the current degradation of agricultural land is caused by soil erosion (Angima et al., 2003). Erosion by water, at a global scale, is the main soil degradation process in agricultural areas (Woldeamlak and Sterk, 2002). It generates strong environmental impacts and major economic losses from decreased agricultural production and from off-site effects on infrastructure and water quality by sedimentation processes (Zinabu et al., 2002; Daba, 2003; Haregeweyn et al., 2005; Amsalu et al., 2007).

Soil erosion creates severe limitations to sustainable agricultural land use, as it reduces on-farm soil productivity and causes food insecurity (Tadesse, 2001; Sonneveld, 2002; Beshah, 2003, Moges and Holden, 2006, Woldeamlak, 2007). In most developing countries, including Ethiopia, human activity triggers these losses (Mohammad et al., 2001, Belyaev et al., 2004, Woldeamlak and Sterk, 2005, Hurni et al., 2005). This is associated with rapid population growth, poor attention to the basic natural resources (soils, water and vegetation), and the need to maximize production to meet the needs of the growing population (Shiferaw and Holden, 1999, 2000, Bewket, 2002, Feoli et al., 2002). This situation is more serious in poor developing countries like Ethiopia (Feoli et al., 2002), where subsistence production predominates. The Ethiopian farmer, who on average cultivates one hectare of food crops and keeps some livestock, is nowadays dependent on natural conditions and cannot tolerate further deterioration of soil productivity (Sonneveld and Keyzer, 2003). Increasing population, intense land cultivation, uncontrolled grazing, and deforestation often lead to, or exacerbate, soil erosion (Tadesse, 2001 and Woldeamlak, 2002). These factors undermine agricultural productivity and frustrate economic development efforts, especially in developing countries where there is heavy land dependence (Shiferaw and Holden, 2000) in low external-input farming systems (e.g., the Ethiopian highlands).

The visible erosion features, such as rills, gullies and concentrated accumulations, are features that often indicate hot spots, those parts of an area that are seriously affected by soil erosion (Mitiku et al., 2006). Rills are very shallow channels that are formed by the concentration of surface runoff along depressions or low points in sloping lands. Rill erosion is the very visible mechanism of soil loss from sloping, cultivated land. Soil erosion that occurs in areas between rills by the action of raindrops (causing splash erosion) and surface runoff (causing sheet erosion) is called inter-rill erosion. Compared to sheet erosion, rill has an entirely different characteristic. It removes a considerable amount of topsoil greater than sheet/inter-rill erosion (Nyssen et al., 2004). Through rills, eroded particles are transported quickly over a large distance. Large particles are more effectively transported. Rills differ from gullies in that they are temporary features and can be easily destroyed during plowing, whereas gullies are more permanent features in the landscape. Rills and gullies constitute an “embryonic” drainage system (Mitiku et al., 2006), which, if unchecked, will develop eventually in to badlands. This may involve irreversibility of the land to put it back into crop production in agricultural systems that are based on animal-drawn implements for cultivating the land (Mitiku et al., 2006).

Many issues and decisions on conservation cannot be addressed solely through technical expertise or science because they are linked to the social environment, economic environment, perceptions and knowledge of nature conservation. Farmers’ perception of land degradation by erosion is a key social factor that is also important in deciding options for controlling soil losses (Graaff, 1993). Some authors who studied in different parts of Ethiopian highlands reported that farmers are more likely to adopt conservation measures in plots that are highly prone to soil erosion, such as plots where slopes are steep and erosion features are visible (Shiferaw and Holden, 1998; Bekele and Drake 2003; Gebremedhin and Swinton 2003). Amsalu and Graaff (2006) concluded that under the current conditions in the Ethiopian central highlands, soil and water conservation interventions should consider farmers’ conservation knowledge and practices to improve the possibility of acceptance and adoption of the recommendations. Farmers rather frequently reject newly introduced SWC technologies even when they are aware that the measure protect and improves productivity of their lands. It is obvious that the newly introduced SWC technologies need to be evaluated not only for their technical efficacy but also for the probability of their sustainable adoption and utilization by the land users. The latter requires identification of barriers to and facilitators of adoption of the technologies. Once the barriers and facilitators are identified, recommendations can be made on appropriate steps that need to be taken to enhance the adoption of the technologies and to effect sustainable land use (Amsalu and Graaff, 2006).

Any conservation program may not be successful without prior consent of the concerned body, the farmers. Thus, understanding farmers’ knowledge and their perception and factors that influence their land management practices are of paramount importance for promoting sustainable land management and also it is important to identify the goals of the farming community; how they view the problem of SWC; what knowledge they had about it and their way to achieve it (Singh et al., 1993). During the qualitative part of this study, we attempted to understand farmers' knowledge and perception on soil erosion features, processes and their perceived causes.

1.2. Statement of the problem

In Ethiopia 85% of the population is directly supported by the agricultural economy. However, the productivity of that economy is being seriously affected by unsustainable land management practices both in areas of food crops and in grazing lands (Berry, 2003). Among the various forms of land degradation, soil erosion is the most important and an ominous threat to the food security and development prospects of Ethiopia and many other developing countries (Wogayehu, 2003) including Delbo Wogene Watershed.

Soil erosion is a serious threat for environmental degradation in the mountainous landscape of Ethiopia in both its economic costs and the areas affected. The hill slopes are under cultivation with limited use of control measures and appropriate land management practices that result in low productivity, physical and ecological degradation. Soil conservation and management practices do not correspond to the activities imposed on these land units. Poor land and water management practices and lack of effective planning and implementation approaches for conservation are responsible for accelerating degradation on agricultural lands and siltation of lakes, dams and reservoirs downstream. Mismanagement of the land is responsible on the land users themselves by assuming lack of their environmental awareness, ignorance or lack of responsibility due to the fact that they cultivate the land for immediate livelihood goals.

Failures in SWC suggest that more detailed information should be used for appropriate layout and design of SWC measures – particularly where run-on and erosion occur – what type of SWC is needed, and exactly where. It is also suggested that the performance of SWC should be better monitored over time. Rills and gullies indicate critical locations of a slope section, because runoff concentration is high. Knowing the critical locations of a slope means being able to minimize the risk of irreversible damage, to avoid failure with SWC, and thus to make it more efficient (Herweg and Stillhardt, 1999). For a specific area, it is therefore necessary to consider where, and how to start soil and water conservation. As a principle of erosion control, physical soil conservation measures should be built on critical locations where rills start to occur.

In the study area, extensive parts of agricultural lands are eroded every year and most of these lands (cultivated) are changed in to rills, gullies and other environmental erosion indicators. Most of the problems are formed due to human activities. Rills are common at the agricultural landscape in the watershed which if not properly managed will advance into gully formation. Numerous rock exposures on the agricultural fields of the area still show sign that the top soils are eroded. Erosion assessments, particularly rill erosion, is not only used to estimate the magnitude of spatial soil erosion damage but also used as a cost effective and simple assessment tool to plan and evaluate the layout and design of SWC.

The study was undertaken in Wolaita Zone, Sodo Zuria Woreda particularly in Delbo Wogene micro-watershed with the following motivations for the selection of the watershed. Firstly, it is typical of the south central highlands of the country in terms of various environmental attributes such as topography, soils, climate, and the socio economic environment. Secondly, the watershed is part of the highlands that are known producing regions, but presently resources threatened by soil degradation and impeding food insecurity (Gete, 2000). Moreover, information about the amount of soil loss and its severity on the agricultural land has not been studied and documented in this particular watershed. Also the perception held by farmers about the extent of soil erosion severity and their attitudes for introduced soil and water conservation technologies, and extent of use of the technology are not investigated rigorously in the study area. The amalgamation of local conservation knowledge in erosion assessment may offer many advantages for SWC planning. Thus, the focus of this study was to asses, analyze and document the problem of rill erosion in the cultivated landscape within the Delbo Wogene micro-watershed to address the identified knowledge gaps.

1.3. Objectives of the study

The overall objective of the study is to assess the rill erosion and evaluate farmers' perception of soil erosion in the Delbo Wogene micro-watershed, Southern Ethiopia.

1.3.1. Specific objectives of the study

- ✓ To estimate soil erosion rate along the slope cultivated lands using field methods (volumetric measurement) of rills and Universal Soil Loss Equation (USLE model) for Ethiopian condition.
- ✓ To assess farmers' perception of erosion indicators and causes
- ✓ To evaluate farmers' awareness of the existing SWC measures and to identify constraints for their adoption.

The study attempted to explore the following research questions:

1. What are the extents of soil loss due to rill erosion and its damage at different slope positions in the

Delbo Wogene watershed?

2. What are the local erosion indicators, from farmers' perspective, on different slope positions of cultivated land of the study area?
3. What are the farmers' perception, awareness and knowledge on the existing SWC measures and their adoption constraints?

2. MATERIALS AND METHODS

2.1. General description of the Study Area

2.1.1. Location and Geology

The Delbo Wogene micro-watershed is located at about 8km North-East of Sodo town which is located 327 km South of Addis Ababa and 154 km far from Hawassa, the capital of SNNPR state. Geographical extent of the watershed is between 06°52' 45.9" and 06°53'34.8" N latitude and between 37°48' 10.5"and 37°48' 42.4" E longitude, with altitude ranging from 2100 to 2300 m.a.s.l. It has a total area of 498 ha. The geology of the study area is dominated by ignimbrite belonging to the Dino Formation of the Quaternary volcanic (Tefera et al., 1996) cited in Ashenafi et.al (2010). The study site has been progressively cleared for agriculture and timber extraction over the past 50 years, and has been degraded from erosion, mudslides and depletion of groundwater due to inadequate recharge capacity (Tefera et al., 1996) cited in Ashenafi et.al (2010).

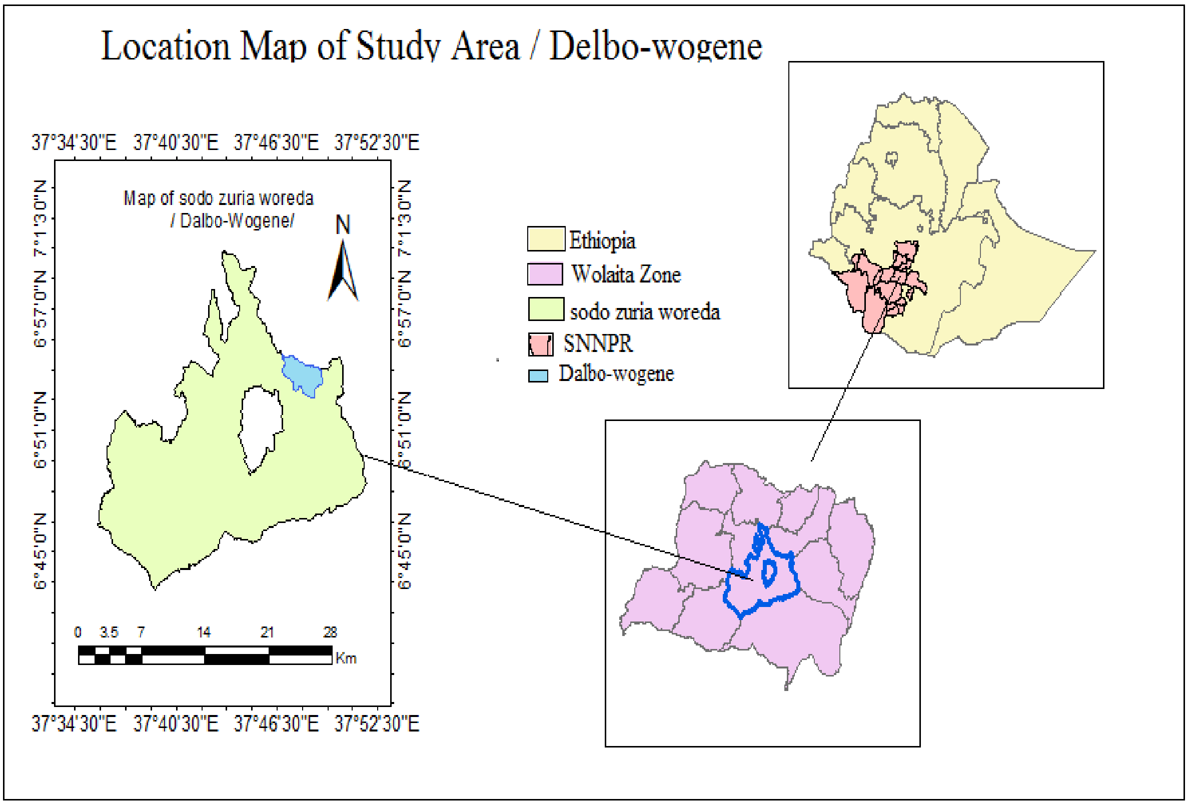


Figure 5: Map of the study area in relation to SNNPR and Sodo Zuria Woreda

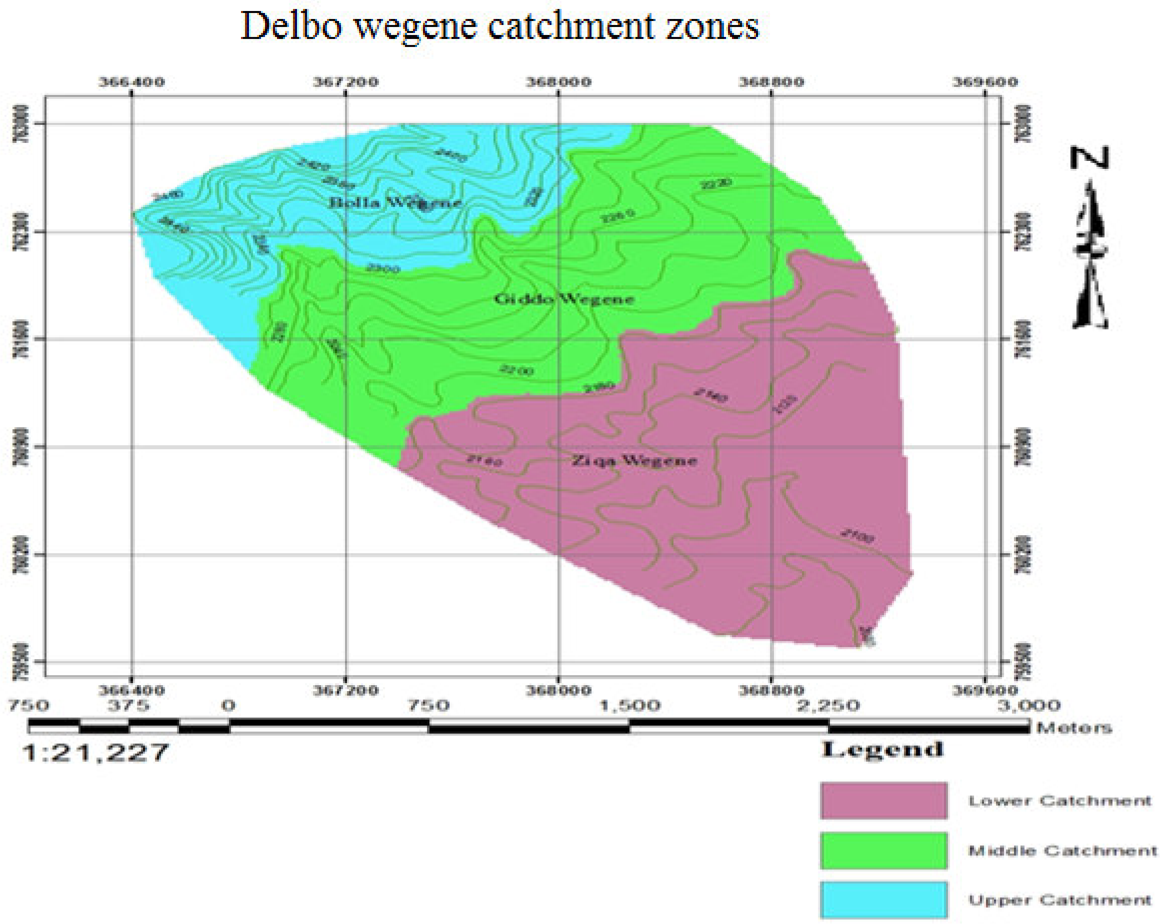


Figure 6: Location map of the study catchment

2.1.2. Natural vegetation

The major crops and vegetation in the Delbo Wogene area include Wheat (Triticum vulgare), Barley (*Hordem vulgare*), sweet potato (*Ipomoea batatas*), Potato (solanum tuberosum), Horse bean (vicia faba), Maize (*Zea mays*), and grasses such as *Digitaria diagonalis*. Besides these, the vegetation is dominated by eucalyptus trees (*Eucalyptus camaldulensis*), as homestead and farm forest. Remnants of indigenous tree species such as podocarpus, junperous, croton, cordia and ficus are present. The loss of forest cover has adverse effect on livelihoods of communities and as well as biodiversity. The land use class extends over the entire site, and is broadly classified as 'shrubland'. Substantive decreases in the quality and quantity of water percolating to groundwater across the watershed have been prominent.

2.1.3. Soils

The soils on the study area have been cleared of perennial vegetation in the past and due to the steep terrain are highly eroded, resulting in the regular impact of flash flooding and mudslides to the villages below in the wet season. The dominant soils of the area are reported to be Nitisols (FAO/UNESCO, 1974), which are sesquioxidic and moderately to strongly acidic (Mesfin, 1998). Fikre (2003) also confirmed the occurrence of Alfisols around the same area. In addition, according to Mulgeta (2006) Ultisols, Inceptisols and Entisols are present around Wolaita area on diverse topography. An increase in agricultural production, particularly rain fed cropping, is a function of soil, climate and agro-technology. The proper understanding of the nature and properties of the soils of the country and their management according to their potentials and constraints is imperative for maximization of crop production to the potential limits (Abayneh and Brehanu, 2006).

2.1.4. Rainfall

In terms of moisture regimes, Wolaita is classified as moist sub-humid. According to the traditional classification, it is in the Weyna Dega altitudinal belt (Weigel, 1986a). Wolaita has a bi-modal rainfall pattern that extends from March to October. The first rainy period (Belg) occurs in March to May, while the second rainy period (Kremt) covers July to October, with its peak in July/August. The average annual rainfall over 43 years is 1014 mm. The mean annual rainfall for the decades of the 1970s, 1980s and 1990s was 1,015mm, 920 mm and 1,290 mm, respectively (NMSA, 2000). According to the SCRPs data (SCRP, 1996b), the mean annual rainfall at Gununo station is 1,314 mm. The average annual rainfall between 2002 up to 2011 was 107.7mm with a maximum of average annual rainfall 134.4 mm in 2007 and a minimum of 75.9mm in 2002. The rainfall follows a Bimodal annual distribution with more than 72% of the annual rainfall during the four months from April to August (locally called kiremt). It is in this season that the major agricultural activities, such as plowing, sowing and weeding are performed. The dry months are between November and March (locally known as Bega) when less than 6% of the total annual rainfall occurs. The Kiremt season (April – August) is more dependable for farming activities.

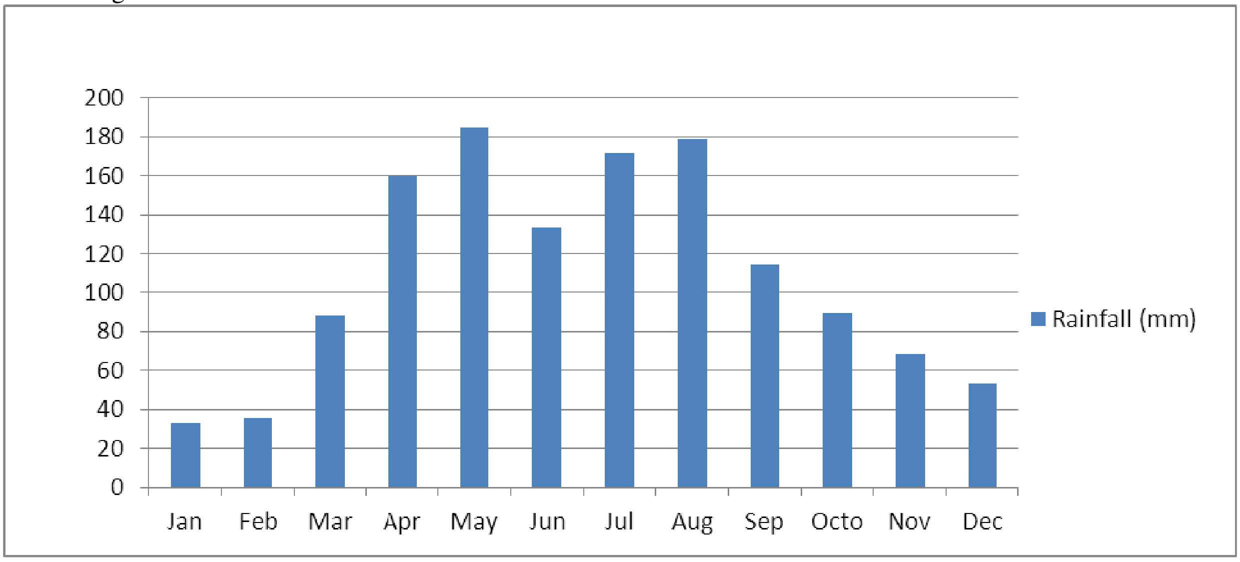


Figure 7: Average rainfall data for 10 years (2002-2011) from Wolaita Sodo station

2.1.5. Temperature

The coldest and warmest months are September and March respectively. The mean annual temperature in Wolaita is 19.5^{0}C. According to the records of ten years (2002-2011, Appendix 17, Table 3) of meteorological data for the Wolaita Sodo station (8km from the site), the climate can be characterized as follows: maximum annual temperatures occur in November and February and ranges from 20.14 to 26.72^{0}C whereas; minimum annual temperature occur in April and September with a range of 10.66 to 11.59^{0}C over the 10 years. Since the watershed lies at a higher elevation, temperatures are often slightly lower while rainfall is likely greater.

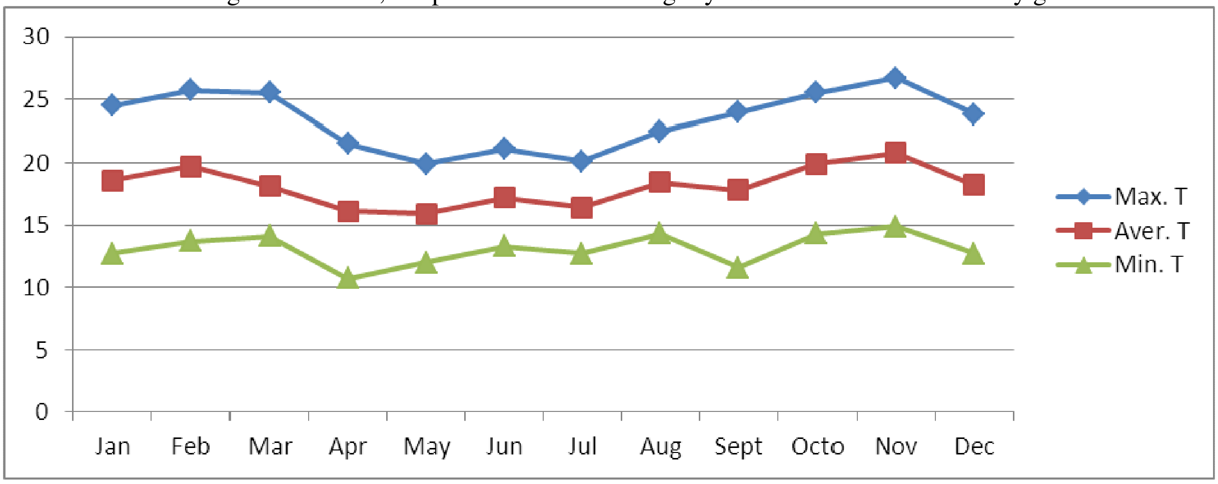


Figure 8: Average temperature data for 10 years (2002-2011) from Wolaita Sodo Station

2.1.6. Farming systems and livestock

Wolaita has an enset-based mixed farming system, where Enset (*Enset evetricosum*) is a co-staple food together with cereals, roots and tuber crops (Westphal, 1975). Like everywhere in the highlands of Ethiopia, livestock is an integral part of farming. Farmers rear cattle, sheep, goats, chickens and equines.

Agriculture in Delbo Wogene watershed is rain-fed, with a subsistence mixed farming system.

A subsistent mixed agriculture, involving cropping and livestock rearing, forms the basis of the economy of the study area. Barley (*Hordeum vulgare*), Sorghum (*Sorghum bicolor*), Maize (*Zea mays*), Wheat (*Triticum vulgare*) and Haricot bean (*Phaseoulus vulgaris*) are the major crops cultivated during the rainy season (Alemayehu, 2007, cited in Ashenafi, et.al. 2010) The dominant vegetables grown in the area are potatoes, tomatoes, onion, Enset (*Enset eventricosum*), carrot, cabbage and fruits. In the study area currently livestock are limited by a lack of grazing facilities, as land is ever more intensively used for arable production which provides the staple foods necessary for family subsistence. Fewer livestock means less manure. This in turn means that less manure is available to bring fertility, structure and water holding capacity to the soil. Reduced grazing land also means less fuel, and a greater proportion of dung having to be used for cooking (Pound and Ejigu, 2005).

2.1.7. Demographic features

Agro-ecology of the Wolaita Zone is 35 percent Kolla, 56 percent and 9 percent Woinadega and Dega, respectively. In those three major agro-ecologies more than 1.5 million people live in the Zone. The Zone is a highly populated area of the country, with 390 people per square kilometer (GFDRE, 2008; Getahun, 1984; SNNPRS, 2008). The regional average population density is 110.2 persons per square kilometer (CSA, 1998). In this Zone there are 12 Woreda, Soddo Zuria Woreda, where the study was conducted, is one of them and has a population size of 163,771 (GFDRE, 2008).

According to the Sodo Zuria Woreda BoARD Office for the year 2011/12, the Delbo Wogene watershed has total 439 household heads of those 388 male and 51 female HHs; with the total population size 3614 of which 1813 male and 1801 female respectively.

2.1.8. Slope Characteristics

The landforms are characterized by rolling to hilly and flat to undulating plain surfaces. According to the Sodo Zuria Woreda BoARD, (2012) the study area was classified into three land forms, of which 75% slope, 10% plain and 15% valley.

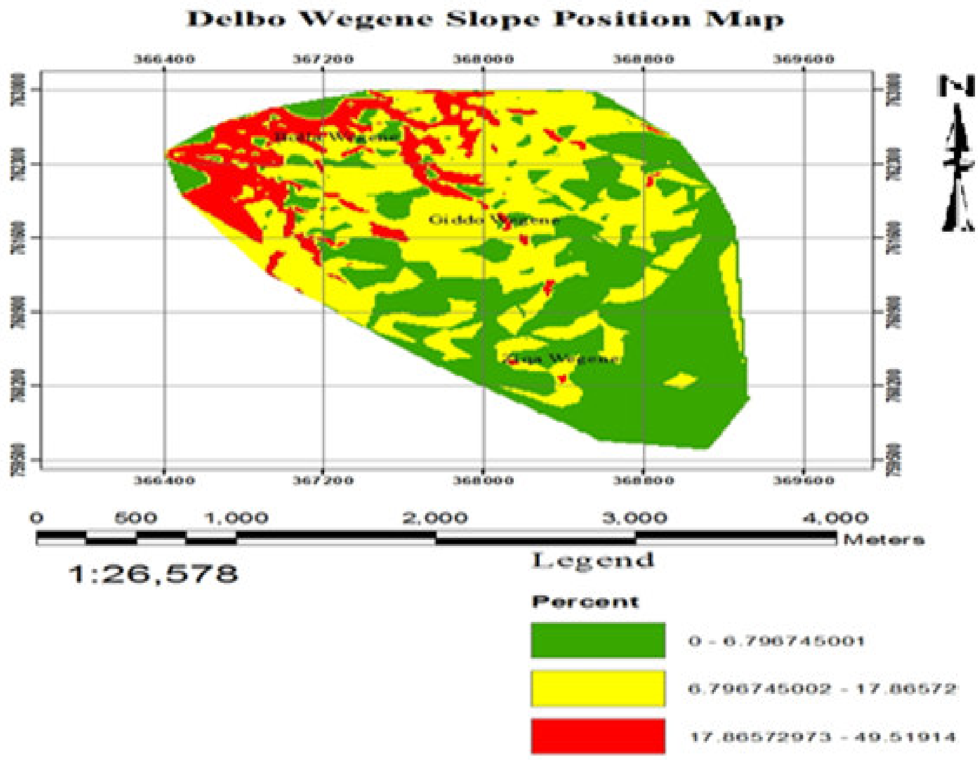


Figure 9: Map of the slope positions of the DelboWogene area

2.2. *Study design and data collection methods*

The research involved two major components for gathering the necessary information. The first component involved the assessment of soil losses from rills on cultivated fields of different slope positions in the study area. The soil loss in each of the surveyed fields was estimated by using universal soil loss equation (USLE) model adapted for Ethiopian conditions by Hurni (1985). The second component was participatory data collection approach; fields transect walks, and key informants interview and focus group discussions, and household surveys were conducted to understand farmers' perception of erosion indicators and to evaluate farmers' knowledge of existing SWC practices. The methods are discussed in detail in the following sections.

2.2.1. Selection of the sample fields

To estimate soil loss from rills on cultivated fields, twelve representative fields, i.e. four fields from each of three slope zones, (i.e. approximately 1% of the total 498 hectare field area) were selected this is due to the study was field scale so it needs large skilled and labor man power, budget constraints, the season which the data collection have been taken in rainy season and the researcher believed that it can represent the whole watershed were some of the reasons for the selection of one percent of the area. According to FAO slope classification criteria the topographic positions of the surveyed fields were classified into three slope zones: upslope zone (18-32%) which is moderately steep, mid slope zone (8-17%) which is sloping and down slope zone (0-7%) which is gently sloping fields. Afterwards, the sample fields were selected using homogeneity criteria of management and cropping history, slope characteristics and conservation practices (Appendix 5) for detailed characteristics of the sample fields. They were defined according to their positions from the up-slope edge of the watershed.

2.2.2. Assessment of rill erosion

Assessment of soil losses from rill erosion was carried out using both quantitative and qualitative aspects. The quantitative aspects considered the magnitude of rill erosion damages through the measurement of the length, depth and width of rills at several points on fields and counting rills after the rain storm (June-August, 2013). These measurements allow determination of rill volumes, which in turn allows obtaining average magnitudes and rates of soil erosion for the fields (Woldeamlak, 2003).

A series of transects across the slope with an average distance of 20m between two transects were established; positioned side by side to minimize rill measurement errors and marked using sticks and stones (Hudson, 1993). During the months of June, July and August when the greatest rainfall amounts causing significant soil loss were recorded. Though the channel size and shape of rills had a great influence on measurement accuracy (Casalí et al., 2006), the morphological characteristics (length, width and depth) of the rills were carefully sectioned and measured along two successive transects. The lengths of rills were measured from its starting point up to the place where the eroded soil was deposited. The widths and depths of the rills were measured at several points along a rill to give a better approximation of a mean width because the width varied along the rill (Herweg, 1996). Totally, three periods of rills' dimensional measurements were made (See Appendix 9). The first, second and third survey periods were in the June, July and August respectively. This is due to concentration of intense and erratic tropical rains in these periods; the soils in these periods of the year become at field capacity and the crops did not provide sufficient cover for the soil.

To quantify rill erosion damage in terms of soil loss, the following calculations were used. (Million, 1992 *et al)*. In each field, maximum development of rills, both in number and dimensions, were attained through the field survey during June to August, in 2013. After August, the rill dimensions may not show significant change though there was still soil loss as long as there is rainfall. Therefore, the average maximum value was analyzed in this paper to estimate the total soil loss due to rills. The eroded soil volumes, rill densities, area of actual damages and other quantities were calculated from the measured rill dimensions: length, width and depth (Herweg, 1996). The volume of soil loss was calculated using the following formula.

$$V = \sum (LiWiDi)Ni \qquad (3.0)$$

Where V is the volume of rills in m^3/ha, L is the length (m) of the rills, W is the width (cm) of the rills, D is the depth (cm) of rills, N is the number of rills, i is the number of homogeneous dimensions. The calculated volume is equivalent to the volume of soil lost from the formation of the rills. The total volume of soil loss was obtained simply by summing the volumes of all homogenous rill segments as shown in Equation 3.0. The eroded soil volume was also expressed in terms of weight of eroded soil by multiplying the calculated volume by the measured bulk density of the soils at each of the 12 agricultural fields in the study area (Hagmann, 1996). The total soil losses were converted into per unit hectare of land to express the annual rate of soil loss.

The area of actual damage (AAD) per unit hectare was obtained from the product of length and width dimensions of each homogenous rill segment by using equation 3.1. The rill densities were calculated by dividing the total rill lengths, obtained by summing up the length measurements of all the rills, by the area of the surveyed field (equation 3.2).

$$AAD = \frac{\sum (LiWi)Ni}{A} \qquad (3.1)$$

$$D = \frac{\sum (Li)Ni}{A} \qquad (3.2)$$

Where; AAD is the area of actual damage by rills in m^2/ha, L is the length (m) of the rills, W is the width (cm) of the rills, D is the density (m/ha) of rills, A is the area of each field in ha, N is the number of rills, and i is the number of homogeneous dimensions.

The rill densities were also converted into per unit hectare of land. The relationships between soil loss rate, rainfall and crop coverage were analyzed. The spatial variation of rill erosion was analyzed by assessing the distribution of the rate of soil erosion, rill density and areas of actual damage across the surveyed fields in reference to their relative topographic positions (i.e. upslope, mid-slope and down-slope), crop type and type classification. In addition to the soil losses from rills and soil losses in the surveyed fields were also estimated by using universal soil loss equation (USLE) adapted for Ethiopian conditions by Hurni (1985b). Rill erosion damage in terms of soil loss (t/ ha) was calculated by:

$$SL(t/ha) = \frac{Wt.of\ SL(t)}{Field\ size} \times 10{,}000 \qquad (3.3)$$

Daily rainfall data of one rainy season for (April-August, 2013) were obtained from the Sodo Meteorological Station Office and these were used to examine the relationship between the temporal distribution of rainfall amount (Appendix 15) and eroded soil volumes due to rills. Since the station is quite closely located to the research site.

2.2.3. Estimation of soil loss using USLE

Soil loss assessment for the cultivated fields at Delbo Wogene watershed was not only based on the physical measurement of rills but also Universal Soil Loss Equation (USLE) model test (Wischmeire and Smith 1978, which adopted for Ethiopian condition by Hurni 1985) was also used.

According to the USLE, soil loss is the function of six different factors as shown in the following equation. The preparation of values for various parameters including average annual rainfall, slope length, slope gradient, soil color, land cover and management practices were collected in all the surveyed fields and estimated according to Hurni (1985) adapted for Ethiopian conditions, (See Appendix 6 and 7), in order to test the universal soil loss equation (USLE) discussed here under:

$$A = R * K * LS * C * P \qquad (3.4)$$

Where; A= Computed mean annual soil loss rate (t ha^{-1} yr^{-1}), R= Rainfall erosivity factor,K= Soil erodibility factor, L= Slope length factor, S= Slope gradient factor, C= Cover types factor and P= Land management and conservation practice factors.

2.2.3.1. Determining USLE factor values

For this study, twelve representative agricultural fields, four from each slope positions of LS, MS, and US (with a total area 34,800m^2 or 3.48ha) were selected for soil loss assessments of the study area. In this paper, the analysis of each process factor was derived as follows:

A) R-factor

The erosivity factor R was adopted by Hurni (1985) for the Ethiopian conditions based on the available mean annual rainfall P_r was used in this study.

$$R = -8.12 + 0.562 * P_r \qquad (3.5)$$

Where, P_r is the mean annual rainfall in mm.

The mean annual rainfall data of ten years (2002-2011) (Appendix 18 Table3) recorded by the Ethiopian Meteorological Service Agency (NMSA) at Wolaita Sodo station was 1310mm. The R-factor value for the entire catchment was determined to be 728Joul mm^{-2}.

B) K-factor

In this study soil erodibility or the k-factor was estimated based on the characteristics of the soil color (Appendix 6 and 7). Hurni (1985) and Hellden (1987) developed USLE for Ethiopian condition by adapting different sources and proposed the K values of the soil based on their color. In the study area, three soil colors, Black, red and Brown predominates. Thus, a value of 0.15, 0.25 and 0.20 were given to these soil types respectively (Appendix 7).

C) LS-factor

The slope length, L-factor, which is the function of slope length along with the S factor (slope steepness), represent the topographical factor commonly expressed as LS factor. A representative slope length and slope gradient for the study sites under consideration were measured and values were recorded during the field survey (Appendix 7). The slope gradients of the sample fields of the area in three slope zones were estimated using clinometers (Taffa Tulu, 2002). Surveyors' tape was used to measure the slope length. According Wischmeier and Smith (1978), those values were combined into a single index as indicated in the formula below were used to calculate the dimensionless topographic factor (LS).

$$LS = \left[\left(\frac{\lambda}{22.1}\right)^{0.5}\right]\left[\left(\frac{S}{9}\right)^{2}\right] \qquad (3.6)$$

Where, λ =slope length in meter and S=slope gradient in percent.

D) C-factor

The cover factor C is dependent upon the percentage of the rainfall energy intercepted by the crop (Morgan, 1996). Potato (*solanum tuberosum*)is the most dominant crop type (30.5% or 1.06ha of the total area surveyed), closely followed by Horse bean (*vicia faba*) (24.5% or 0.85ha) and Maize *(Zea mayes*) (23%or 0.80ha of the total area). Wheat (*Triticum vulgare*) has the least coverage (22% or 0.77ha of the total area, Appendix 5). Based on Hurni (1985), annual average crop cover factor (C-factor) for the Universal Soil Loss Equation (USLE) is 0.10, 0.15, 0.25, and 0.15 respectively for Wheat, Horse bean, Potato, and Maize (Appendix 7). Hence, Potato (*solanum tuberosum*) and Horse bean (*vicia faba*) have similar effects on the erosion process.

E) P-factor

The management factor represents the ratio of soil loss under a given crop to that of the bare soil (Morgan, 1996). Tillage and planting on contour reduce soil erosion depending on the slope of the land. P values range from 0 to 1, whereby the value 0 represents a very good manmade erosion resistance facility and the value 1 no man made resistance erosion facility is given by Roose (1977) and Morgan (1996). Based on Hurni (1985), the land management practice factor (P-factor) for the study sites was estimated (Appendix 7). There were some agricultural support practices in the study area. Contour ploughing, Intercropping, Mulching and Soil bunds were applied in three slope classes for some cultivated lands in the study area.

2.2.4. Soil Sample Collection and Measurement

To take the soil samples along the slope positions of the representative cultivated fields of the Watershed which was categorized into three slope classes: Lower-slope (LS); Middle-slope (MS); and Upper-slope (US) positions. Twelve fields, four from each slope zones, were selected to represent the surveyed fields. Twelve soil core samples (undisturbed) were collected from a depth of 0-20cmby using cylindrical core samplers of 5 cm in diameter and 5 cm in height (Blake and Hartge, 1986). The cylinders were held in position by special flange to ensure a vertical downward movement when forced into the soil by hammering.

Soil samples were brought to the Sodo Soil test Laboratory station for air-dried and examined for their bulk densities. Bulk density (BD) of undisturbed soil sample was determined using core sampler (cylindrical metal sampler) and determining the mass of solids and the water content of the core, by weighing the 105^{0}C for 24 hours and reweighing after cooling. The dried soil was calculated by subtracting the mass of moisture and core having volume 98.1 cm^3 to get the bulk density of each sample. The samples were carefully ordered at both ends of the sample core to obtain soil samples of predetermined volume. Bulk density was then calculated using equation (3.7)

$$\rho_b = \frac{m_s}{v_t} \qquad (3.7)$$

Where: ρ_b the bulk density of soil (gm/cm^3), M_s= mass of dry soil (gm), V_t = bulk volume (cm^3)

2.2.5. Determination of Household sample size

The recorded total households living in the study area was obtained from the Kebele Administration office and DAs and there were about 439 household heads residing in the area. The study was took place in three slope zones; Lower-slope, Mid-slope and Up-slope area with the respect to their geographical positions. Out of 439 household heads, 218 household heads were residing on down slope area, 125 on moderate slopes and 96 household heads on upper slope zones. Total sample size was determined using the following formula (Cochran, 1977 cited in Habtamu, 2006).

$$n_0 = \frac{Z^2 p(1-p)}{d^2} \qquad (3.8)$$

$$n = \frac{n_0}{1 + \frac{n_0 - 1}{N}} \qquad (3.9)$$

Where; n_0 is the desired sample size for a defined population, n is number of sample size, Z is 95% confidence limit i.e. 1.96, P is 0.1 (proportion of the population to be included in the sample i.e. 10%), q is 1-0.1 i.e. (0.9), N is total number of population and d is margin of error or degree of accuracy desired 5% or (0.05).

As indicated by the calculation, using the above formula, 80 farmers were sampled for the interview. Using simple random sampling technique, the study samples were selected from the list of households. Accordingly, 37 household heads from down slope area, 25 household heads from moderate slopes and 18 household heads from upper slopes were selected using simple random (lottery) sampling method. We preferred using an error margin of 5%. The probability of the sample size has confidence interval of 95 %. Respondents in the study were household head farmers and in cases where household heads were missing, randomly selected household heads were substituted for the missing household heads.

3.3. Community and household surveys

In order to address objectives concerning to second component of this study (participatory data collection) two surveys were carried out in all the three villages i.e. (US, MS, and LS zones) that form the study area Delbo Wogene, from June to August 2013. The survey team consisted of the researcher, Development Agents (DAs) from the Sodo Zuria Woreda BoARD, and the representative village key informants.

In this component (participatory data collection part), the first survey comprising transects walks and farmer groups discussion sessions, focused on the farmers' knowledge and capability to identify existing erosion indicators on the cultivated landscape. Transect walks were carried out in the morning while farmer group discussions in village were held in the afternoons. Using a checklist, transect walks were conducted on village-by-village basis. An issues in a checklist that guided our discussions included: observable erosion indicators (rills, gullies, rock exposures, sedimentation etc), existing SWC measures (their status, & compositions on each field etc), slope gradients and land use patterns (dominant crops), general land husbandry practices (up-down and across slope tillage patterns). During the walks, the researcher and Development agents observed and took note of the level of land degradation and types of erosion indicators associated with water erosion. Farmers described the appearances of each of the indicators observed in various fields and their causes. Other issues discussed in these meetings included: categorization of indicators into those that were observable either immediately after a rainy season/a rainfall event (i.e. current indicators) or as a result of long-term erosion effects (i.e. past indicators). Closer observations were also made in selected sample fields where measurements were carried out. In another separate meeting, the key informants analyzed all the erosion indicators generated by the village groups, to establish the final consensus list of erosion indicators for the study area.

The second survey in this component was to assess individual household's opinions on identification of typical soil erosion indicators that observed on their fields and its causes, their perceptions on soil erosion problems and existing SWC practices and their adoption constraints were collected using formal interviews with the sampled households. The formal interview conducted via structured and semi-structured questionnaires on a randomly selected 80 households i.e., 37, 25, and 18 from Lower-slope, Mid-slope and Up-slope zones of the whole Delbo Wogene KAs respectively. These villages or slope zones were distinguished on basis of how individual farmers carried out farming operations (up-down/across slope direction), soil management practices, and number and type of SWC measures on their fields and their adoption constraints. Farmers were randomly selected for interview (using simple random sampling with replacement) from lists obtained from each village leaders of the area. When the selected households unavailable after repeated visits or specifically stated their unwillingness, the next household on the list were interviewed. To obtain farmers' knowledge and perceptions, interviews were undertaken by going to each interviewee's homestead, special care have been given for the respondents while interviewing them to get sufficient information for the intended study.

A test survey were conducted with 1/4th of the sampled farmers to evaluate the accuracy of questionnaire & the nature of respondents, to estimate the time required to fill a single questionnaire, and to make some minor modifications prior conducting the full survey. The general issues addressed in the questionnaire regarded: some issues of household demographic and farm characteristics, whether farmers were aware that erosion was taking place, how farmers detected the on-site and off-site effects of soil erosion, perceived reasons to the development of erosion indicators, distribution of these indicators along the different slope positions, and Level of awareness and adoption of the existing SWC measures, and constraints to their adoption, if any.

3.4. Data analysis

3.4.1. Social Survey Analysis

The data generated by the structured questionnaires was analyzed using the frequencies and percentages. The data were thoroughly checked by the researcher before the analysis by directly comparing all 80 cases with the original questionnaire. The relevant qualitative information generated by the informal discussions with farmers and other concerned bodies were integrated with the quantitative data for better understanding of the issues covered in the study mostly in form of verbal/narrative information. This information is more qualitative in nature and was used to support the quantitative data analysis. These were written down during the survey and summarized.

4. RESULTS AND DISCUSSION

4.1. Bulk density (g/cm^3)

Bulk density varies among the three slope positions of the area to some extent. The mean bulk density in these slope positions of the study area ranges between 1.17 and 1.24 g/cm^3 (Table 2). An average bulk density of soils under up slope fields was at about 4% higher than mid-slope fields and 7% higher than soils in the down slope fields. This is may be due to shortage of range land, overgrazing observed on cultivating lands, steepness of the fields and cover decline from time to time of the area that leads to more runoff formation then area exposed for stoniness and compactness. Detailed information is attached in the Appendix 15 and 16.

Table 2: Some soil physical characteristics of the surveyed fields in one rainy season (June up to August, 2013).

Topography	Average Bulk density (g/cm^3)	Average slope gradients (%)
Lower slope	1.17	9.8
Mid-slope	1.20	16.6
Up-slope	1.24	23

According to Tan, (1996) cited in Melese, (2010), low bulk density values (1.0-1.5gcm^{-3}) indicates a favorable physical condition of soils for plant growth, while high bulk density values (1.8 - 2.0gcm^{-3}), which indicates a poor physical condition of soils for plant growth. Comparing to this findings, the bulk density result in three slope classes of the study catchment is in the normal soil bulk density range and provides a favorable physical condition for plant growth. According to the study conducted in the same area by Ashenafi, et al., (2010), the bulk density of the soils was ranged in 1.00g/cm^3 to 1.29 g/cm^3 in the fields positioned in three slope positions studied in same methodology. Despite it indicates a favorable physical condition of soils for plant growth; the result indicates that there is fail of soil compaction in the fields in comparison with others finding in the area. This is may be due to practicing of some physical and biological SWC practices in their fields and farmers highly conscious on soil compaction consequences via government and professionals awareness creation works (from field observations and farmers' interview).

4.2. Quantitative assessments of the soil losses *in the study area*

4.2.1. Magnitude and rate of soil loss by rill erosion

The results presented in this paper are based on a comparison of the three slope areas with regard to on-site effects of soil erosion on upper, middle and lower slopes zones, described above, within one rainy season which is from 10 June, 2013 to 18 August, 2013. The analysis gave an overview of on-site soil erosion damage and also covers details about the temporal aspects of erosion.

Rill formation started at the beginning of the rainy season (June). The area exposed for high intensity of rainfall for some time; it allows the soil to increasing risk of erosion. During the survey periods, rills were occurred on all fields of the three slope classes. Rills were more prevalent on the upper slope farms than other slope farms. In the survey periods some of the rills were disappeared after their formation due to deposition of sediments and re-ploughing by the owners of the farms but most rills developed their volumes time to time. Rills have been noticed in a great number in the study area, Delbo Wogene, on agricultural fields. Dominant factors causing these damages may be are poor vegetation cover during rainy seasons, intensive tillage for some crops, which exacerbate soil erosion, as well as rainfall intensities. Soil type and geology are of minor causes, whereas gradients of slopes and slope length strongly influence the development of rills.

Table 3: Measured parameters of rills in the cultivated fields and its damages on three slope classes (US, MS and LS) during three survey phases (June-August, 2013), in Delbo Wogene Micro-Watershed.

Slope positions	Fields in (m^2)	Aver. nº of rills in three measurement	Erosion features			Aver Vol. of SL (m^3)	Aver weight of SL(t)	Aver rate of SL (rills) (t/ha)	Mean AAD (m^2/ha)	AAD (%) via rills	Mean rill density (m/ha)	Inter-rills (30%)(t/ha)	Total soil loss (t/ha)
			Aver. L(m)	**Aver. W(cm)**	**Aver. D(cm)**								
LS	3000	128	10.2	62.0	3.3	26.7	31.2	24.40	632	6.00	1020	7.32	31.7
	2700	164	10.4	70.0	2.8	33.4	39.0	30.40	933	9.00	1332	9.12	39.5
	4200	201	6.60	42.0	3.6	20.0	23.4	18.20	435	4.00	1036	5.46	23.6
	2900	235	9.20	15.6	3.3	11.1	12.9	10.07	253	2.50	1689	3.02	13.0
MS	2600	229	6.50	44.7	2.9	19.3	23.2	19.30	546	5.50	1240	5.79	25.0
	3000	239	9.50	35.3	3.0	24.0	28.8	24.00	662	6.60	1892	7.20	31.2
	3500	226	9.80	42.6	3.1	29.2	35.0	29.10	775	7.70	1845	8.73	37.8
	2900	170	11.2	51.8	3.1	30.6	36.7	30.50	809	8.00	1586	9.15	39.6
US	2200	235	8.80	44.7	2.8	25.9	32.0	32.00	910	9.10	2068	9.60	41.6
	2800	153	14.3	46.7	3.0	30.6	37.9	37.90	1006	10.0	2187	11.4	49.3
	2900	271	8.50	56.7	3.2	41.8	51.8	51.80	1289	12.8	2303	15.5	67.3
	2100	228	8.50	29.7	3.0	17.3	21.4	21.40	562	5.60	1938	6.42	27.8

Due to various factors such as heavy rain storms, frequent cultivation and absence of good vegetation cover, the greatest rill erosion damage occurs at the onset of the rainy season (field observation and farmers). Though, more or less an average number of rills were similar in almost all surveyed fields in three slope zones; the mean soil losses were increased from lower slope fields to upper slope fields in the study area in (Table 3) this is may be due to the topography of the area and the contribution of conservation practices that adopted at lower and middle fields in amount and type in comparison with upper slope surveyed fields.

As shown in Table 4, there was a considerable amount of an average soil loss via rill erosion (i.e. 20.8 t ha^{-1}, 25.80 t $ha^{-1}$and 35.80 t $ha^{-1}$from lower, middle, and upper slope fields respectively). Hence, the average total soil loss assessed from rills was 27.46 t ha^{-1} from rills on lower, middle and upper slope fields. In addition to this, the average total soil loss estimated from three slope fields via inter-rill erosion was8.25 t ha^{-1}. Therefore, the mean total soil loss estimated from both rills and inter-rills was 36.2 t ha^{-1} from total surveyed area of cultivated lands i.e. 3.48 ha in the study area.

Table 4: Review of key values of soil loss which attained via rill erosion survey (10 June, 2013 up to 18 August, 2013) in the three slope zones.

Soil loss parameters	Slope zones LS	MS	US	Mean total soil loss
Soil loss by rill erosion (t ha^{-1})	20.8	25.8	35.80	27.5
Soil loss by inter-rill erosion (t ha^{-1})	6.24	7.74	10.74	8.25
Total soil loss (t ha^{-1})	27.04	33.54	46.54	35.75

As it is difficult to measure inter-rills, the measurement of rill erosion does not consider soil loss from the land between the rills and thus underestimate the actual erosion. According to Zachar (1982), rill erosion underestimates 30% of the actual soil loss. Govers(1991) also reported, as the contribution of inter-rill erosion can be more than 30 % of the total soil loss in fields where rills are present. Woldeamlak and Sterk (2003) cited in Derebe, (2009) also assumed 30% of the actual soil loss to calculate the contribution of inter-rill erosion to soil loss. Also for this study, therefore the researcher assumed that the measured rill erosion rates underestimated soil loss by 30. The contribution of inter-rill erosion can be 30% of the total soil loss.

Hence, the average total actual soil loss via inter-rill erosion was about 8.25 t ha^{-1} for all fields of the surveyed area. The area damaged actually by rill erosion in the sampled fields of the three slope zones was 21.5%, 27.2% and 37.5% on LS, MS and US fields (Table 5) out of sampled area respectively. Though actually damaged area in percent increases from lower slope to upper slope fields, its distribution on some fields in LS and MS is less wide than the US fields even peak rainy season. This was also a sign of the value of SWC practices adopted in this slope fields nevertheless maintained timely.

4.2.2. Classification of rills

As a criterion to classify the rills we looked at the widths of the rills because in most cases it varies much from field to field in the surveyed fields. According to Herweg (1996), rills in the study area were classified as: Small (<25 cm), medium (25-200 cm), and large wide rills (>200 cm). We found that the average number of rills noticed on three slope fields during three survey periods were classified 501 (60%) as small rills, 304 (36.8%) as medium rills and 22 (2.7%) as large rills of the total rills attained (Table 5). Though the number of frequency differs, rills classified as large width were observed in some fields of the surveyed area at the August survey. Especially upper slope fields have no cultural ditches and waterways practiced around it were vulnerable for the occurrence of wide rill channels. In contrast to this fields in mid-slope area have many cultural ditches inside the fields installed by the farmers might have prevented the formation of the large and wide rills. The mean total number of rills were 826, that appeared on 34,800 m^2 or 3.48ha of arable land (taken as a sample field area) with an average area of actual damage of 2937m^2/ha (28.9% of the total sampled area) and average rill density of 6,712 m/ha (Table 5) in the study area.

Table 5: Characteristics of rills which attained via rill erosion survey period (i.e. 10 June, 2013 up to 18 August, 2013) in the three slope zones.

Rill features	Slope zones			Average
	LS	MS	US	
Small rills	421	518	564	501
Medium rills	289	323	300	304
Large rills	18	23	23	21.7
Total nº of rills	728	864	887	826
AAD (%)	21.5	27.2	37.5	28.7
Rill density (m/ha)	5077	6563	8496	6,712

4.2.3. The nature of rill erosion in different slope positions and crop types

Soil losses and number of rills increase for some crops with slope position. An average total soil loss from agricultural cultivated fields in one rainy season in the form of rill erosion alone was 27.5 t $ha^{-1}$from all of the representative sample fields (i.e. 3.48 ha) Table 6. Though all surveyed fields were cultivated, comparison of mean soil loss, which attained in three survey periods in the same crop types at different slope positions, was mandatory. The fields of wheat in the study area was highly affected by rill erosion in comparison with other cultivated crop fields in the second measurement period (i.e. 24 July, 2013) this is due to the cropping period of wheat was in peak rainy season but the cumulative highest soil was lost from potato fields this because all fields covered by potato in the area highly disturbed by owners of the fields during peak rainy seasons. Hence, the rate of soil loss in upper-slope wheat field was 8.3 t ha^{-1} greater than mid-slope wheat fields and 4.3 t ha^{-1} greater than down slope fields Table 6. Though, the slope gradient and slope length were greater on maize upper slope field than the maize field on the mid-slope area which had 7.1t ha^{-1} more soil loss in the upper slope fields. The reason that the maize crops had less erosion in up-slope area due to soil bunds (even unmaintained).

Table 6: Average number of rills in the surveyed fields and their contribution on the rate of soil losses attained from lower, middle and upper field measurements (within one rainy season, June to August, 2013).

Fields in (m^2)	Crops found	Aver. nº of the rills	Aver. rate of SL in t ha^{-1} from June-August			Average rate of SL t ha^{-1}
			LS	MS	US	
7800	Wheat	197	20.2	16.2	24.5	20.9
8500	Horse bean	185	18.8	23.5	29.6	23.1
1006	Potato	232	14.3	25	35.3	24.8
7900	Maize	211	20.1	22.6	15.5	17.3

In general, the average highest rate of soil loss in the study area was recorded from potato fields (i.e. 24.8 t ha^{-1}) and the least average rate of soil loss recorded from maize fields (i.e. 17.3 t ha^{-1}) Table 6. Soil loss rate in maize crop fields was less than from other three agricultural fields of the surveyed area. Rill erosion in a maize field were small in comparison with other fields since the surface before and after planting were rough and also due to shortage of farm lands most farmers in the area practiced intercropping especially in mid-slope surveyed fields in view of the fact that main rainy season. This increases infiltration, which in turn decreases runoff that was considered as the major source of rills and sheet erosions in the area. The leaves of maize protect the energy of raindrops in the rainy season.

4.3. Soil Loss and its influencing factors in Delbo Wogene watershed

4.3.1. Effects of temporal rainfall to rill erosion formation

As observed during survey, the life span of rills was not uniform throughout the wet season. Most of the shallow rills lost their depths and widths by sediment redistributions and by the time, the crop covered the soil. Some of the rills joined to other wider rills and after a while, they would disappear.

Table 7: Average measured dimensions of the rills during the survey seasons and their cumulative rate of soil loss from the study area.

Months	RF for ten days in (mm)	Average n^{o}of rills	Aver. L (m)	Aver. W (cm)	Aver. D (cm)	Vol. of SL(m^3)	Weight of SL (t)	Cumulative rate of SL (t/ha)
June	178.9	191	8.70	38.5	2.7	17.3	20.7	5.94
July	281.9	511	9.60	50.2	3.0	73.8	88.5	31.3
August	254.8	826	10.7	54.0	3.3	157.4	188.8	85.5

According to Herweg and Stillhardt (1999), soil loss depends largely on the time of the year when the rains occur. As of the group discussion and personal interviews, it was reported that rill formation started at the beginning of the rainy season when the most fields are bare. Though the study had begun lately after ~10% of rainfall passed, the field survey showed almost the same result with the interview. There was no high rainfall recorded to erode significant amount of soil loss compared to June, July and August months.

According to Branu et al., (1997) the rain is concentrated into a three-to four-months period in the kiremt, with more than 72 percent of the highlands receiving over 600 millimeters of rain between May and September. Most of the rills noticed during at the first survey developed their volume from time to time and the peak cumulative erosion was which accounted (5.94 t ha^{-1}) in the June , (31.3 t ha^{-1}) in the July and (85.5 t ha^{-1}) in August (Figure 10). This result showed similar findings with Herweg, et al. (2002). According to Hurni, (1986) soil loss on cultivated land is estimated to be more than 80% of the eroded annual soil loss occurs in last month of the rainy season. Moreover, the third survey in (18 August, 2013) implies the highest soil loss which is (63.2%) in comparison with first and second surveys (Figure 10). In general, the average total soil loss via both rills and inter-rills accounted within the three survey periods in the area was 36.2 t ha^{-1} (Table 8). Hence, change in magnitude of rill erosion was observed at the August,

Table 8. This finding is in agreement with findings by Woldeamlak and Sterk (2003) and Herweg et al (2002).

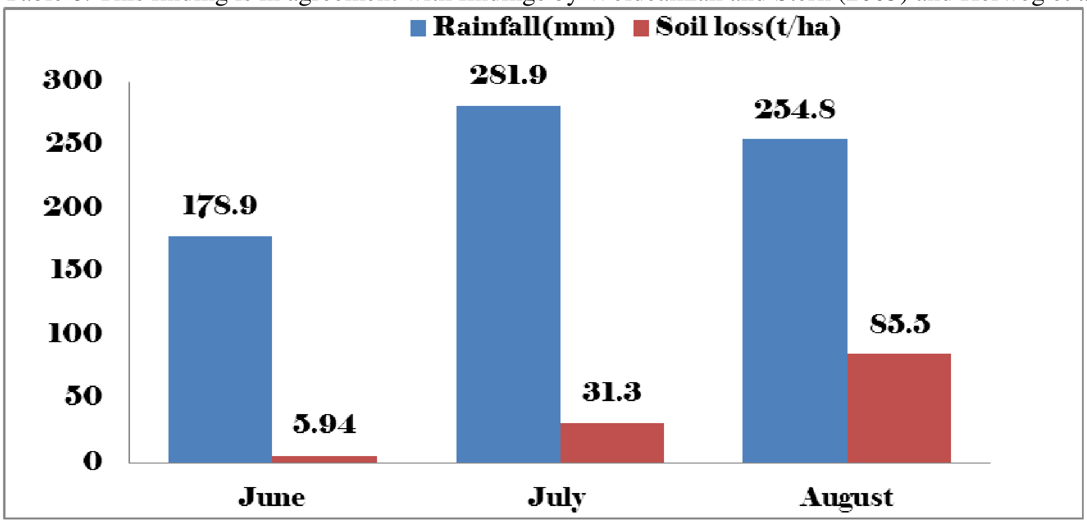


Figure 10: Extraction of the five most erosive rainfall months from monthly precipitation within the study area (June-August 2013).

Therefore, a large amount of annual soil loss was occurred during a few rainstorm periods (Herweg and Ludi, 1999). The generated runoff from these periods was the most important direct driver of severe soil losses. Rills were initiated mostly by these few destructive storms, but their continued growth throughout much of the wet season was the effect of the cumulative rainfall (Woldamlak and Sterk, 2003). Therefore, the effectiveness of SWC technology depends on the extent to which it can resist such ‘extreme’ rainstorm periods.

4.4. Estimated soil loss using USLE at Delbo Wogene watershed, Southern Ethiopia

According to the assumption, the annual soil loss listed in the (Appendix 7) from the twelve surveyed fields was estimated in (Table 8). The values of all USLE factors of each cultivated fields are indicated in (Appendix 6 and 7). Therefore, the product of all factor values gave the amount of mean annual soil loss rate (i.e., 48.6 t ha^{-1} per year).

According to Edwards, (1987) the predictions match USLE field measurements in cropping land best, because the model was initially built from that type of data. Nevertheless, the predicted long-term averaged erosion rates for cropping land can differ from the field measurements, due to our assumptions that the cropping lands were under conventional cultivation with stubble retained cover management. The results in this study estimated by these model for Ethiopian condition approximately matches (i.e. 48.6 t ha^{-1} per year) the result which assessed through direct measurement (36.2 t ha^{-1}) for one rainy season (i.e. June-August, 2013) indicates that both soil loss assessment approaches used was best estimations for soil loss due to rill and sheet erosion. The study made by Woldamlak and Sterk, (2003) indicates that the rill survey approach gives good semi-quantitative information on soil erosion in real life situations of diverse farming and land use practices in a quick and inexpensive way.

In general field scale surveys of erosion, particularly rills have a vital role to play in the sustainable management of agricultural lands. Without involving expensive instrumentation and sophisticated technologies, this strategy may yield more economical (and efficient) solutions in local areas than the application of the existing generation of erosion models (Herweg, 1996; Woldamlak and Sterk, 2003).Therefore, rill survey method can be concluded as a central way to quantify soil loss at field level and to plan effective and site dependent SWC measures. Since USLE can be used to compute the total average annual soil loss from sheet and rill erosion within a particular watershed, the soil loss from these erosion features were calculated to compare with the measured soil loss (Table 8).

Table 8: Comparison between mean measured (for three periods of June-August, 2013) and predicted soil loss in Delbo Wogene Watershed (see appendix 6 and 7) how each parameters were estimated.

Topography	Surveyed fields in(m^2)	Mean measured SL due to rill(t ha^{-1})	Soil loss due to inter-rills (30%) (t ha^{-1})	Total SL (rill + inter-rills)t ha^{-1}	USLE Predicted Soil loss (t ha^{-1} year)
Lower slope	3000	24.40	7.32	31.7	13.2
	2700	30.40	9.12	39.5	18.3
	4200	18.20	5.46	23.6	39.3
	2900	10.07	3.02	13.0	20.7
Middle slope	2600	19.30	5.79	25.0	40.4
	3000	24.00	7.20	31.2	46.2
	3500	29.10	8.73	37.8	48.5
	2900	30.50	9.15	39.6	51.4
Upper slope	2200	32.00	9.60	41.6	52.4
	2800	37.90	11.4	49.3	65.7
	2900	51.80	15.5	67.3	112
	2100	21.40	6.42	27.8	83.7
Mean total	**34,800**	**27.8**	**8.34**	**36.2**	**48.6**

As described above, total soil loss due to both rill and sheet erosion was estimated as 36.2 t ha^{-1}, which is equivalent to 3.6mm yr^{-1}. Hurni, (1993) estimated that soil loss due to erosion from cultivated fields in Ethiopia amounts to about 42 t ha^{-1} year. In addition, the mean annual total soil loss estimated through Universal soil loss equation model (USLE) was 48.6 t ha^{-1} per years. However, it is within the range of soil erosion rates measured in the Anjeni, 17 t ha^{-1} year to 176 t ha^{-1} year. Herweg and Ludi, 1999), the estimated mean soil loss rate (sheet and rill) in the Delbo Wogene Micro-Watershed is higher than the average rate of estimated to occur from cultivated fields for the country.

4.5. Farmers perception on erosion indicators and SWC practices

4.5.1. Identification and Description of erosion indicators

There is an increasing need for assessing indicators for land quality. At least three indicators can be of value in indicating the quality of land: stability of plant production; in the form of crop and pasture yield assessment from year to year; visible signs of land degradation as evidenced by excessive erosion and runoff, declining biodiversity and biomass; and what farm families themselves perceive as a change. Different measurable erosion indicators give evidence for erosion hazard or its impact.

While each indicator has its own attributes and applications, several indicators together can piece together a far more comprehensive and consistent picture of erosion along the topo-sequence and the whole catchment. Different applications of erosion indicators are highlighted here: to show both the process and likely cause of land degradation through time, to provide evidence and magnitude of erosion, to bring individual indicators together for comparative and overall assessment, including how to develop a procedure for getting an overall picture to assess and evaluate erosion as well as to plan SWC.

Farmers were aware of different erosion indicators that indicate the extent and distribution of local erosion problems which they observed during their daily farming activities. Among many indicators farmers listed out the most common ones that often used to describe the severity of erosion and/or degradation at individual plot as well as catchment scale. Farmers identified a consensus list of erosion indicators, which they clearly described. They also outlined what they perceived as the determining factors or causes leading to the development of these indicators. Seven common erosion indicators were identified and described by farmers of the Delbo Wogene area as follows:-

Rills or micro-channels on the fields

Rill erosion as indicator of significant seasonal erosion is the center of focus of this research project. Through visual monitoring of rill formation and the rill network development on agricultural fields immediately after erosive storms, it can be easily identified erosion risk areas to plan effective erosion control technologies. Soil erosion professionals may consider erosion problem from rill channels with depth 1-2cm. However, perceptions of erosion problem by farmers were realized from rill channels defined with depth more than 5 cm and length greater than 4m. Continuous and closer field inspection will increase farmers' perception on rill erosion. In-depth characteristics of rill formation and development and also its frequent on-site effects were presented in the chapter four of quantitative assessment section.

Figure 11: Actively forming rills on cultivated lands during the study period in Delbo Wogene watershed in Sothern Ethiopia, Photo by Abebayehu in July, 2013)

They are observed immediately after a rainfall event commencing in the early part of the rainfall season. The channels are also found to start at the base of the crop stock. The local language name means literally a flow path that flows over the soil surface, leaving channeled surface that shows the lines of the flow. The flow paths can either be narrow or wide and sometimes long or short depending on slope and encountered obstructions during the rainfall event.

Sedimentation

The local language name means literally "covering or burying". It describes the effect of the surface runoff water, through sheet wash or rill features, leaves when it comes against a barrier, depression or lacks transport capacity. Where sedimentation was observed some farmers mentioned improved soil fertility whereas others mentioned lower fertility conditions. The former is when the deposits are dark in color leading to improved yields whereas the latter (infertility) occurs when the material consisted of red or stony soils overlaying the darker soils.

Figure 12**:** Accumulation of sediment behind erosion control structures in maize and Horse bean fields in the study area (Photo by Abebayehu, 2013).

Loose soils or/and soil color changes

Literally means soils without strength or "weightless", and could be lifted by water or wind easily. This indicator presents poor soil structure and low soil-water retention capacity since plants tended to quickly wither at the onset of dry periods. This indicator describes the color of remaining soil; turning from dark to red. This was an indication that dark top soil had been removed by water erosion. They also referred to such soils as infertile or had grown "old" meaning the topsoil had gone leaving sub-surface soil layers, which were no longer producing high yields. In the region, 5-7 times tillage and packing of the fine seedbed by animals is a common practice for some crops like tef, carrot and wheat. This reduces infiltration, smoothens the land surface and consequently low surface storage leading to high runoff and soil loss. Farmers in the study area perceived the existence of soil erosion due to its felt effects over time. They were explained that the proportion of the different soil types is changing with time. Such change is attributed mainly due to soil erosion and tillage intensity. The high rate of erosion is caused mainly by vegetation clearance and intensive tillage. As farmers soil color and texture change, and its position in the landscape are important criterion for farmers, to evaluate their soils.

Figure 13: Soil color change occurred in Barley and Maize fields in some surveyed fields (Photo by Abebayehu, 2013)

Crop root exposure

It was literally meaning seeing exposed crop roots. This happens when the soil around the stem of the plant was removed. Exposed roots caused crops fail to stay in an upright position, forcing them to bend due to canopy weight or force of wind and could also wither off. Plants, especially legumes, with their superficial roots exposed were considered to be easily uprooted by sheet wash or overland flow. Formerly highland (Deriya) areas were used to grow only few crops including Barely and cool season grain legumes due to the low temperature. This was particularly attributed to deforestation. One farmer from Delbo Wogene explained this situation as the "Maize and Teff crops are climbing to the mountains, and forests were disappearing." Longer effects of degradation process results in the exposure of root system of the crops/trees that is quite a good indicator of local erosion.

Figure 14: Top fertile soil loss from Teff field that exposing crop roots (Photo by Abebayehu in July, 2013)

Rock exposures or/and stoniness

This indicator means sparsely scattered rock outcrops. Farmers observed this in places with shallow soil depths, which once washed off by rill erosion the rocks were exposed. Some farmers said that rocks were "growing" though they hardly noticed any significant increase of rock "growth" in their generation.

Figure 15: Rock exposure in carrot fields at the lower slope (Photo by Abebayehu in July, 2013)

Gullies

Literally meaning big or large channels, differentiated from rills by their sizes. Farmers distinguished gullies from rills when a child of seven years old couldn't jump across. They were more common along the footpaths (aligned along the slope direction) and in fields adjacent to roads or home compounds with container covered houses. But also identified in fields lacking SWC measures and either with few or widely spaced/wrongly designed SWC measures, water diversions and road constructions.

Figure 16: Actively forming and expanding gullies in the watershed (Photo by Abebayehu in July, 2013)

Broken SWC structures

Referred to gaps or breaking in SWC structures that occurred due to the force of runoff water from upper slopes. The gaps implied that severe erosion had taken place. The failure of one SWC structure could result in subsequent erosion damage in other downhill fields, creating both the gullies and breaking of other structures or infrastructures.

Figure 17: Broken SWC structures that exacerbating soil loss in the Upper part of the study area (Photo by Abebayehu in July, 2013).

4.5.2. Perceived soil erosion indicators

The majority of the farmers noticed and reported that the occurrence of rill erosion was the dominant erosion feature (73%) on their farmlands. This percentage of respondents also compared rill erosion problem as the highest with other erosion features. Gully erosion was also reported by 43% of farmers along their farm boundaries and waterways, while broken SWC structures 58%, sedimentation 49%, soil color change 45% and crop root and field rock exposures 34 & 26% were farmers' perceived erosion indicators respectively (Table 9).

Table 9**:** Farmers' perceived soil erosion indicators on their farms and environment, based on 80 respondents (local names in parenthesis) of Delbo Wogene Watershed, Southern Ethiopia, 2013.

Note: Percentage added up to more than 100 percent as farmers have mentioned more than one indicator

№	***Number of erosion indicators perceived by farmers***	***№ of respondents***	***%***
1.	Rills (*dioy medhiyo ogiya*)	58	73
2.	Sedimentation *(Maalla*)	39	49
3.	Crop root exposure (*Kattaa xaphoy qoncciyiooga*)	27	34
4.	Rock exposure (*shuchay shooqan konccibettiyoga*)	22	28
5.	Loose soils/ soil color change (Eesuwara denddiya biittaa)	36	45
6.	Gullies (*Bohuwa*)	34	43
7.	Broken SWC structures (*morettida biitaanne haatta nagiyo hiilla*)	46	58
8.	Others	26	33

Though farmers identified and believed for having numerous seasonal erosion indicators and their severity in their naked eyes in their fields and catchments, they usually do not perceive the long term consequences of the seasonal erosion features in the form of rill erosion channels, stoniness, sedimentations and others. On the contrary, those indicators such as gullies and yield reduction etc., which have already brought an economical and environmental damage to the locality, were easily realized by farmers, even if these are beyond their capacity to control and costly. Farmers have given priority to do control measures for such long term erosion indicators rather to prevent the seasonal erosion indicators before developing to uncontrolled stage.

Farmers provided the following common erosion indicators on cultivated fields: exposure of crop roots on the surface; sedimentations at the end of the fields, soil texture change to gravel or rock fragments, exposure of rock surfaces, surface soil wash and rill channel formations and gullies. Farmers in the area recognized the various soil erosion processes, some of the responses were; when there is over flow of constructed ditches and damage their crops; when there is siltation in and out of their fields mostly at the lower field borders; when rills appeared on their fields, when the color of soil in the upper part of the field goes to yellow or red whereas the lower part goes to black. Farmers are aware of the consequences of soil erosion currently; its existence in the absence of SWC measures will worsen the situation.

4.5.3. Classification of erosion indicators

According to farmers, erosion indicators were classified into current and past indicators. Past erosion indicators were observed after several cycles of erosion events that lasted at least three months (one rainy season) or several years of rainfall events. Current erosion indicators could be observed after a single or up to three rainfall events (Table 10). Farmers observed that current erosion indicators could easily evolve into past erosion indicators if erosion controls measures were not applied.

Table 10: Farmers' classification of soil erosion indicators.

Current erosion indicators (reversible)	**Past erosion indicators (non-reversible)**
Rills Sedimentation Root exposure (in food crops) Broken SWC structures	Rock exposure Red soils or soil color change Gullies

These findings suggest that farmers are aware of both the short (current indicators) and long-term (past indicators) impact of soil erosion on their land. Despite the knowledge and evidence of these indicators, farmers were less worried by the formation of the current erosion indicators. They perceived them as reversible because they would be obliterated seasonal through ploughing and weeding. Besides, sedimentation would hardly be observed as a problem to most farmers as it represented an area of high soil fertility. According to Lal and Elliot (1994) cited in Okoba and Graff, 2005 that observed current erosion indicators were easy to permanently reverse by change of land use and land management practices that improved soil structural stability and organic matter content. Farmers who did not take permanent remedial action on current erosion indicators, more permanent, spatially distinct and irreversible forms of erosion indicators tended to develop and remain exposed on the soil surface.

4.5.4. Perceived causes of soil erosion indicators

Farmers observed that most of the erosion indicators developed after combined influence of some determining factors: rainfall, steep slopes, scarcity of grazing lands, population pressures, damage of conservation structures, lack of vegetation cover and poor farming practices. Though the degree of influence varies, all of these factors affected the development of environmental erosion indicators such as, rills, gullies, soil color changes and others. As a major cause of soil erosion, absence of vegetation cover and excessive rainfalls were ranked for first, 65% and 61% respectively (Table 11).

Table 11: Farmers' perceived causes of the soil erosion (n=80).

Reasons of soil erosion formation	Rank			
	1st	2nd	3rd	4th
	%	%	%	%
Excess rainfall	**61**	**41**	**31**	**22**
Deforestation	**30**	**43**	**25**	**15**
Lack of vegetation cover	**65**	**26**	**19**	**10**
Damaged SWC practices	**55**	**48**	**29**	**21**
Steep slopes	**50**	**47**	**17**	**11**
Scarcity of grazing land	**36**	**27**	**23**	**14**
Population pressure	**47**	**34**	**25**	**16**
Improper farming practices	**41**	**26**	**20**	**13**

Note: Percentage added up to more than 100 percent as farmers have mentioned more than one reason.

According to farmers, the rainfall pattern has changed since the last 10-20 years; the rain has become more intensive; occurring in few months than it used to be (see Appendix 18 table1). Over half of the farm plots managed by the total respondents were located on slopes having more than a 10% gradient. Given higher rainfall conditions, farm fields on steep slopes will exhibit high erosion potentials (Nyssen, et.al, 2004). Farmers also recognized the effects of slope on soil erosion. Yet, high respondents indicated or ranked first that damaged conservation structures and steepness of the slopes were (55% and 50%) escalated the problem of soil erosion, especially upper slope field owners.

Other authors have reported on farmer's knowledge of erosion processes that are in agreement with our findings. Nepalese farmers observed the formation of splash pedestals and runoff development underneath the tree canopies, which they attributed to wide tree canopies (Joshi and Sinclair, 1998) cited in Okoba and Graff, 2005. Though Zulu community did not recognize splash erosion phenomenon but rills and gullies were clear features on their farms (Van Dissel and De Graaff, 1999). Rwanda farmers used soil surface characteristics that developed as a result of soil erosion to identify different productivity zones and types of soils (Steiner, 1998).

4.5.5. Farmers' estimation of erosion damage

The qualitative assessment is not an individual tool as it does not quantify any measure (Pyke et al., 2002). To supplement the quantitative information this preliminary evaluation is recommended if the goal is a better certainty of the results of the assessment. According to our discussions with the key informants, they perceived that there was an association between erosion indicators and perceived soil loss levels. But they stated that they were unable to estimate actual soil loss from their fields other than relating certain on-site erosion effects (erosion indicators) to different soil loss rates (Table12).

Table 12: Farmers' qualitative estimation of soil loss rates using soil erosion indicators.

High erosion rate	Moderate erosion rate	Low erosion rate
Sedimentation	Red soils or soil color change	Root exposures (food crops)
Gullies	Rock exposure	Sheet wash
Broken SWC structures	Rills	-

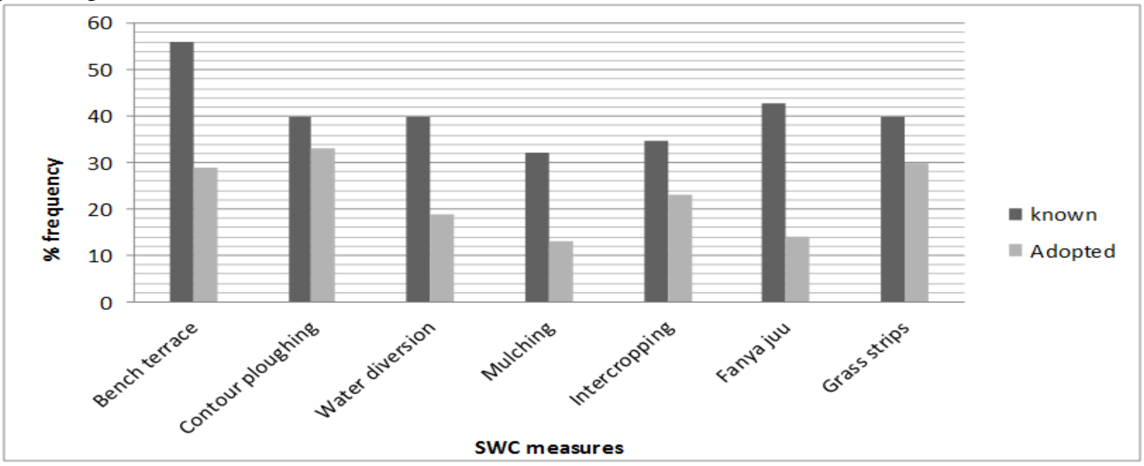
Other findings on farmers' perception also illustrate the common practice of farmers relating erosion indicators to soil degradation by erosion. The association of certain indicators to a particular level of soil loss rate can in some cases dependent on soil conditions, type and rainfall amounts. A survey by Kirkwood and Dumanski (1997) on expert farmers of Prairie province, Canada, associated small rills to slight (low) erosion while larger rills and small gullies, sedimentation and stoniness were an indication of moderate erosion. Only gullies, among our list of indicators, were associated to severe (high) erosion. Despite failing to recognize the phenomenon of splash erosion, rills and gullies were associated to high erosion rate by small scale farmers of South Africa according to Van Dissel and De Graaff (1999).

Differences between scientific evidence and farmers' perception are clearly obvious on how the effects of sheet erosion on soil and crop yields are perceived. While scientists have evidence that sheet erosion (sheet wash) has the most severe damage on soil productivity (Rickson et al., 1993), our farmers and other studies on farmers' perceptions of soil erosion perceived otherwise (Östberg, 1995; Kirkwood and Dumanski, 1997). This is probably because of lack of dramatic evidence of decreased crop yields and masking effect of deep top-soil depth layer during the early stages of soil erosion process.

4.6. Farmers' awareness of soil and water conservation measures

There were differences in level of awareness and adoption of SWC measures among farmers in the study area. However, Figure 18 shows general trends of *known and adopted SWC* options in the area. *By known SWC measures* the researcher mean that the farmer had knowledge of such a conservation option whereas *by adopted*

SWC measures the researcher mean that the farmer had already installed such a conservation option either by own choice or through government support. In general most conservation practices such as; bench terraces, contour ploughing, fanya-juu, and mulching and water diversion were widely known but the level of adoption varied significantly from field to field in three slope classes. Contour ploughing was the most widely adopted SWC measure followed by bench terraces, intercropping and water diversion. Least recognized or adopted SWC measures were the grass strips, mulching and fanyajuu Figure18. Though water diversion recognized by most farmers, due to the topography of the area was steep slope and susceptible for runoff it only adopted by a small percentage of the interviewed farmers.



Note: Percentage added up to more than 100 percent as farmers have mentioned more than one reason.
Figure 18**:** Level of known (aware of) and adopted (already installed) SWC measures

The multipurpose role and benefits from grass strips could explain the high adoption rate. Grass strips serve as a main source of fodder for livestock as well as a good filtering hedge against runoff water. It is also used to stabilize risers of fanyaajuu terraces. Farmers would tend to go for short-term return systems rather than labor intensive conservation systems (Thomas, 1988). Awareness and adoption of bench terraces and fanyajuu measures can be linked to colonial legacy whereby these measures were adopted by force (Wenner, 1981; Ståhl, 1993; Kiara et al., 1999). Interestingly, though the high-density tree-crop integration system observed in the research area and in the whole of Delbo Wogene area, the results of this study do indicate that the contribution of trees to SWC was not recognized by farmers.

All the interviewed farmers perceived soil erosion as a problem constraining crop production. They reported that the most important top soil for crop production activity was deteriorating over time due to erosion processes. Hence, they observed frequently how the loss of soil from cultivated fields has been reducing the depth of the topsoil through time and the number of erosion indicators such as stoniness, rills and others in their farmlands has been increasing over time. Moreover, when soil depth decreases the unproductive soil (locally called “ladaa” or sometimes “ottaa”) will be left. This “ladaa” soil is not productive. This phenomenon was common in the watershed.

Tree planting has always been promoted foremost as a source of construction timber and fuel-wood but not for soil erosion control, given that their dominant niches are on farm boundaries. Farmers viewed trees as a great source of farm cash income, given the restriction to logging in Government forests. According to Tyndall (1996), elsewhere in the central highlands of Kenya, found that farmers were not willing to adopt trees within cultivated field as SWC measures, except on boundary niches, primarily because they were good life fences which ensured land tenure security.

4.7. Constraints of SWC practices

Soil and water conservation measures are not sufficiently adopted in the study area. Though farmers showed motivation to adopt and know SWC structures, they are reluctant to practice these measures to their farmlands. This does not mean that no conservation measures adopted in the study area, Delbo Wogene. Farmers listed several constraints when they faced adopting SWC measures. It was considered that how farmers who had already adopted some kind of SWC measures on their fields experienced these constraints. Mainly to establish types of constraints experienced by farmers with a different number of adopted SWC measures (Table 13).

Table 13: Farmers' reasons for not adopting SWC measures on their farms based on the (n=80 respondents).

Options	№ of respondents	Percentage
Lack of labor	60	75
Lack of capital/ money	55	68
Small farm size	43	53
Lack of tillage tools	33	41
Lack of technical know-how support	40	50
Women headed households	26	32
Land tenure security	21	26
Others	19	23

Note: Totals over 100% are due to multiple responses.

Generally, the main constraints were insufficient labor force and lack of money to undertake conservation measures. From the interviewed farmers, 75% reported that some conservation measures like terraces, bunds and fanyajuu were labor demanding and time consuming for construction (Table 13). Lack of money (68%) was the other constraint that farmers facing not to practice new technologies on their farms to proceed their products and productivity. The other issues that affected their conservation practices were lack of technical know-how support (50%) from the agricultural experts to construct bunds and terraces (locally known as kiyessa). In the group discussion and informal interviews, lack of kiyessa was the big issue raised by the participants, which is under other options they provided.

The next important constraints were lack of tillage tools (41%) and shortage of farm size (53%). Land tenure security (26%) and women-headed households (32%) were least recognized constraints to the adoption of SWC measures Table 13, against popular beliefs (Khasiani, 1992; Stahl, 1993; Tenge, et al., 2004). In particular, the women-headed households were not regarded as a barrier to adoption of SWC measures given the emphasis by SWC program donors on gender considerations when designing and planning for SWC measures (Pretty et al., 1995). Also level of education exposing traditions that biased against women in Africa has improved women participation in SWC programs (Pretty, et al., 1995). Therefore the cause for the current low motivation to increase and maintain the number of SWC measures might be due to adoption constraints, listed in this study, and others possibly not identified. With regard to land tenure security, most farmers in the study area have little deeds but still those who did not have were assured of security of ownership from the head of the family. Hence the lack of it would not hinder installation of SWC measures if one wished to do so.

For example, farmers who wanted to construct with his indigenous knowledge like terraces and if his neighbor does not, the runoff will not drained out, as the owner of the down slope fields does not permit to receive the runoff since he did not construct some conservation measures like the one who did. However, they underlined, "if there were kiyessa, all the farmers would construct", "even tomorrow morning". However, they also assured that the office designed strategies to apply the technology based on the farmers' indigenous knowledge. The experts added that farmers have awareness to the technologies but are unwilling to implement except few in the district.

One other important finding from this study was that some of the listed adoption constraints (Table 13) likely to be more of a problem with less number of SWC measures adopted. This was particularly noted with regard to lack of labor and capital. Possibly because the more SWC measures a farmer had, the more effective erosion was controlled. And this leads to higher productivity and higher cash income and help to solve other typical constraints experienced by small-holder farmers. Similar constraints have been observed elsewhere by others (Tenge et al., 2004).

Farmers during personal interview and group discussion were recommended what should be done as a solution to improve the effectiveness of SWC measures. They suggested: (a) most farmers do not have materials to construct terraces and bunds. Therefore, the concerned body like government should support in this regard; (b) technical support from experts to design the SWC measures is mandatory; (c) though farmers have awareness to soil erosion problem, continuous training and experience sharing and incentives should be given for the community to understand and implement the new SWC measures; (d) efforts should be taken until farmers show willingness to adopt/adapt the technology; (e) if there is accessibility of grasses and trees seedlings, they have dual purposes: for forage and for soil conservation measures.; (f) government should not only mobilize people for one period conservation works but also should also mobilize for maintenances via professionals advice.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

In this study we analyzed the extent of soil erosion rate in the cultivated fields of Delbo Wogene Watershed by using a number of methods such as the volumetric measurement of rill channels, and soil loss prediction model (USLE) and environmental factors that contributing cultivated lands to the soil losses were also identified and discussed and in addition to this household assessments regarding to soil erosion processes, problems, their causes and constraints of SWC measures. The amount of soil loss from cultivated fields in the study area is well above the tolerable range estimated for the country. Soil erosion was under a serious problem in agricultural fields particularly the upper part of the study catchment. This is shown by the high total soil loss rate from cultivated lands, which has reflected on changes in soil physical properties.

Since soil erosion is highly variable in time and space, one-rainy season is a rather short time for final conclusions concerning the above results. Brazier (2004) and Vandekerckhove et al. (2004) stress that the value of such field surveys increases with the length of observation by affording a valuable long-term perspective on rates of change of soil erosion. Herweg and Stillhardt (1999) reply that apart from average rates and conditions, which may provide an overview and assist in an appropriate interpretation of soil loss results, it is the extreme behavior of soil erosion that makes it possible to address the temporal (periods of high and extreme erosion) as well as the spatial aspects (critical locations) and therefore leads to detailed information about when and where erosion occurs.

Based on the above statements, we draw the following conclusion for the study areas:

- The average total rate of soil losses from the area was 36.2t ha^{-1} which via rills and inter-rills from (lower, middle and upper slope cultivated fields) during three survey periods.
- An average total damage by rill erosion in the area was 28.7% of the total surveyed area from which 21.5%, 27.2% and 37.5% damages were recorded on LS, MS and US fields
- Of the total surveyed area (i.e. approximately 3.48 hectare cultivated fields) around 37.3% of the area was affected via (both rill and inter-rill) erosion damage;
- Vegetation cover (as a product of crop type, soil management and rainfall intensities) are the most important factors controlling soil erosion rates;
- On average, about one-third of all rainfall events classified as erosive according to Wischmeier and Smith (1978) led to actual erosion damage.
- The sampled household farmers in Delbo Wogene Micro-watershed are well aware of the problem of soil erosion by water 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.
- This research demonstrated that farmers' knowledge of indicators of erosion closely matched scientific erosion assessment condition.
- All indicators mentioned by farmers were positively correlated to erosion, and the number of farmers' indicators per field increased with erosion intensity.
- The overall output from the research showed that if appropriate interventions are not carried out in the study area for the future, soil erosion rate would escalate and reversing the process would become difficult.

5.2. Recommendations

Based on the results of the study, the following recommendations are forwarded:

- The farming technology which the farmers use and the types of crop they cultivate render the land vulnerable to erosion both by rain and wind, the area that this study conducted was not different from this, as crop rotation could reduce erosion, but because of land shortages farmers are reluctant to use crop rotation. It is essentially recommended that the public should agree to adopt changing to crops that need less tillage and improve the soil structure which can reduce the problem of erosion especially at the rainy season.
- Most of the farmers in the area have no sense on rills formation on their fields; it is kindly recommended that farmers should pay equal attention for rill erosion with the gully and other erosion indicators.
- Land management practices such as agro-forestry systems, conservation tillage and suitable SWC structures, such as hillside terracing, soil bunds, waterways, grass strips etc. and re-vegetation of the upland areas on damaged cultivating lands especially on the embankments should be practiced.
- Maintenance and strengthening the existing structures should be practiced in the study area with a full consensus and participation of the dwellers by giving attention to keep the standards of physical structures.
- A more participatory approach is needed to employ the farmers' knowledge of erosion indicators for identifying degraded areas, and semi-quantify soil damage.
- The use of erosion indicators identification and computing the equivalent soil damage approaches could significantly facilitate development agents (DA) in assisting farmers in targeting specific areas that require conservation attention.
- Further studies should be made to get more information about the damage of soil erosion by water on the cultivated land and other related impacts on the dwellers of study catchment.

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