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Evaluation of Biological and Bio-physical Soil and Water Conservation Methods at Haro-Sabu, Kellem Wollega Zone of Oromia, Ethiopia

Tamasgen Mosisa
Soil and Water Engineering Researcher, Haro-Sabu Agricultural Research Center

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Abstract
The work compared bio-physical soil and water conservation technique against biological and farmers practice. This evaluation was undertaken at the experimental farm of Haro Sabu Agricultural Research Centre (*Awetu Gandaso*), Dale Sedi district for five consecutive years. A field experiment was designed in RCBD, replicated three times on the field. Soil loss and runoff volume from the experimental fields were measured using at collection champers installed at the downstream end of each plot. Results were compared on the basis of effectiveness of soil and water conservation. The results illustrate that the bio-physical soil and water conservation technique was more effective in controlling soil and runoff losses when compared to the other two techniques. In comparison with Farmer Practice, biophysical approach saved soil from erosion by 44% on the cultivation land. Thus biophysical soil and water management would be an important technique to be considered to improve the current on soil and water conservation.
Keywords: OARI, SCRP, Conservation, Ethiopia

1. INTRODUCTION

1.1. Soil Erosion and Conservation

The reduction in the capacity of the land to produce benefits from a particular land use under a specified form of land management is land degradation (Blaikie and Brookfield, 1987; Blaikie 1989). On the other hand, according to Douglas (1994) and Hurni (1993) the unhindered degradation of soil can completely ruin its productive capacity for human purposes and may be further reduced until steps are taken to stop further degradation and restore productivity. Ethiopian western region is experienced with humid, high-rainfall area where soil erosion and nutrient leaching is the limiting factor for long-term cultivation (Mitiku *et al*., 2006).

Besides soil losses, it is important to consider runoff losses in the viewpoint of soil and water conservation. Soil and water conservation is usually provided from the viewpoint of agricultural engineering. However, the loss of rainwater as runoff limits the water available for crop production (Nyssen *et al*., 2005). It is also important to consider soil erosion in affecting the soil nutrient equilibrium. Land degradation is severe in Ethiopia; governmental and non-governmental institutions have invested huge financial and labor resources to tackle land degradation problems (Nyssen *et al*., 2000). Promotion of sustainable land management technologies such as soil bunds has been suggested as a key strategy to reduce land degradation and increase crop production (Shiferaw and Holden, 2000). Accordingly, some successes of soil bunds have been recorded which reduced soil loss considerably (Adimassu *et al*., 2014).

Soil erosion is among the soil degradation processes, which directly correlated to soil productivity. Two forms of soil erosion can be distinguished: soil erosion by water and wind. Soil erosion by water is the most prominent one (Mitiku *et al*., 2006). Ethiopia was among the most serious soil erosion areas in the world (Hurni, 1993). Although the magnitude varies, several studies confirmed that the significance of soil erosion in the Ethiopian Highlands ranged from 42 t/ha/year (Hurni, 1993) to 179 t/ha/year (Shiferaw and Holden, 1999). This situation may not different for western Oromia where high annual rainfall pronounced. Mitiku *et al*. (2006) graded the most important causes of soil erosion by water as deforestation (43%), overgrazing (29%), and agricultural water management (28%).

Agricultural water mismanagement can be improved at farm level by improving agricultural land management practices. Conservation agriculture is amongst the improved practices that can prevent soil loss from the field. The improved practice can be plough direction (along the contour), tillage frequency (minimum), soil and water conservation activities. Soil erosion by water from agricultural land usually occur with sheet erosion which the thin topsoil that can remove the most fertile part so that the fertility of the soil can considerably be declined.

1.2. Soil Conservation Research Programs (SCRP)

Soil Conservation Research Program (SCRP) was initiated in 1981 under the Ministry of Agriculture, and after seventeen years of field research it was decentralized in 1998 when the research sites were brought under the responsibilities of regional authorities. The research concept of the SCRP involved the selection of benchmark sites with various socio-cultural settings in several different agro-climatic zones of the country (Mitiku *et al*., 2006).

1.2.1. SCRP in Eritrea

Afdeyu from highland of *Eritrea* have the lowest erosivity (soil losses measured on test plots of 17 - 19 t/ha/year) measured in the SCRP sites, due to the lowest rainfall it received. About 28 to 38% of the annual rainfall leaves the cultivated test plots as runoff, but only 6% of the annual rainfall leaves the catchment as river discharge.

1.2.2. SCRP in Ethiopia

Anjeni (research site established in 1984 for *Gojam*) received the highest annual rainfall of all SCRP stations and was characterized by very high erosivity (plot soil loss values of 131 - 170 t/ha/year) were recorded.

In *Hunde Lafto* (established by 1982 at *Hararghe*) annual rainfall and annual erosivity are moderate (soil losses are 22 to 25 t/ha/year). On plots, only 3 to 5% of the annual rainfall leaves a field as runoff, while discharge at catchment level accounts for 9% of the annual rainfall.

Maybar was established by 1981 in *Wello* where high rainfall and moderate erosivity were experienced. Only 9 to 16% of the rain leaves the plots as runoff, and 27% leaves the catchment as river discharge. Soil losses on plots (32 to 36 t/ha/year).

Despite very high rainfall and erosivity, *Dizi* (established in *Ilu-Aba-Bor* by 1988) has the lowest runoff and river discharge of all stations. Both values are around or below 5% of the annual rainfall. Deeply weathered soils and dense plant cover with a good rooting system allow most water to infiltrate. In addition, evaporation is high. The test plot soil loss values are also the lowest measured (1 to 4 t/ha/year).

Although annual rainfall in *Gununo, Wolayta* (established in 1982) was high, its average sediment yield remains below 1 t/ha/year. This is due to plant growth is not limited by moisture stress and temperature; both high evaporation and infiltration reduce surface runoff and river discharge.

Andit Tid (established in *Shoa* by 1982) is experienced with high annual rainfall, high erosivity and steep slopes, thus is prone to severe erosion. It is located above 3000 m above sea level, where low temperatures limit vegetation growth. Soil losses on test plots range from 87 to 212 t/ha/year. Structural conservation can reduce these amounts, but annual values recorded on experimental plots were still above 30 t/ha/year.

1.3. Objectives

The objective of the study was to compare amount of soil loss by water erosion and runoff generated during main rainy period of the year (from June to October) under biological and biophysical soil and water conservation measures against the control. The treatment with minimum sediment and runoff losses are then to be recommended as the more effective conservation measure, thus better if verified and used on the farm. In order to achieve those objectives, the runoff and soil loss from the treatments were directly measured during the experimentation period and analyzed.

2. MATERIALS AND METHODS

2.1. Study Site Description

This study was conducted for five consecutive years from 2012 to 2016 at the experimental farm of Haro Sabu Agricultural Research Centre (*Awetu Gandaso*), Dale Sedi District, which is located in Kellem Wollega Zone, Ethiopia (Latitude 8.9030°N, longitude 35.2267°E and 1526 m above sea level) (Figure 1). Haro Sabu is the district capital, located to west at 548 km from capital Addis Ababa on the Nekemte – Dembi Dolo main road. Agro-climatically, it is located in sub-humid tropical zone. Soil is Nitosol. According to the weather station from the National Meteorological Agency the mean annual rainfall is 1020 mm, with most of it occurring during the spring and summer months. The minimum and maximum average air temperatures of 12.71°C in December and 25.07°C in March occur.

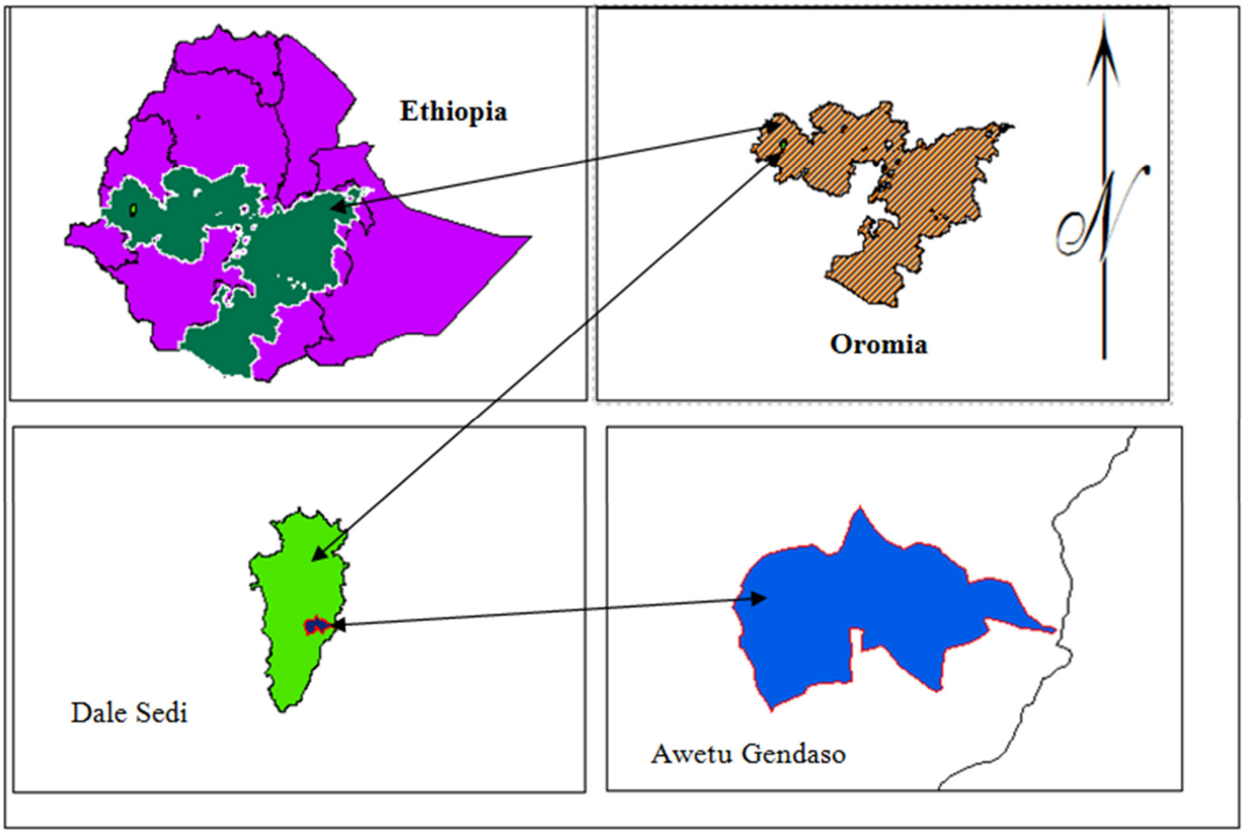


Figure 1. Map of Study Area

2.2. Cropping Pattern

The major crops grown at the study site are pulse and oil seed (soybean, haricot bean, ground nut and sesame), cereal (maize, sorghum, finger millet and rarely teff), horticultural crops (potato, tomato, hot pepper and sweet pepper). They are the staple food of the living community. Coffee is the major cash crop of the district (as many districts of the zone), thus, coffee is income generating commodity.

As the usual practice of the district, the experiment was done following the cereal – pulse and oil seed rotation in order to restore soil fertility and enhance the production. Specifically, the maize – soybean crops rotation were used interchangeably throughout the experimentation period.

2.3. Experimental Setting and Field Layout

Treatments were laid out along the contour by Randomized Complete Block Design, replicated three times each. Their mean results are used for each three times replicated experimental units.

Each experimental plot has a common dimension of 16 m long x 4m wide, having an average slope of 12.6%. Cutoff drain was made during the implementation of the experiment and maintained regularly when needed, the plots were also bounded by thin sheet metal up to 30 cm above ground, securing the *insitu* soil and water conservation: no runoff including the splash erosion from external was allowed to enter the plot. The detached soil by rainfall only from the experimental plot was thus allowed to be conveyed to 200 lit and 60 lit containers installed at the bottom of each test plots; the soil loss (sediment yield) and runoff from the plot was then collected to the containers. From those containers, the sediment weight and runoff volume was measured at 9A.M (3 o'clock local time) regularly for five consecutive years during summer season.

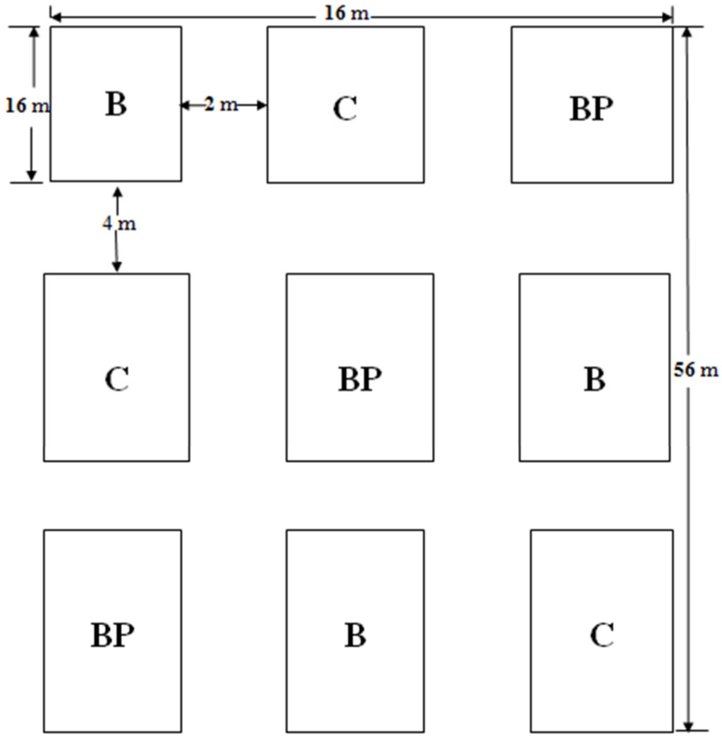


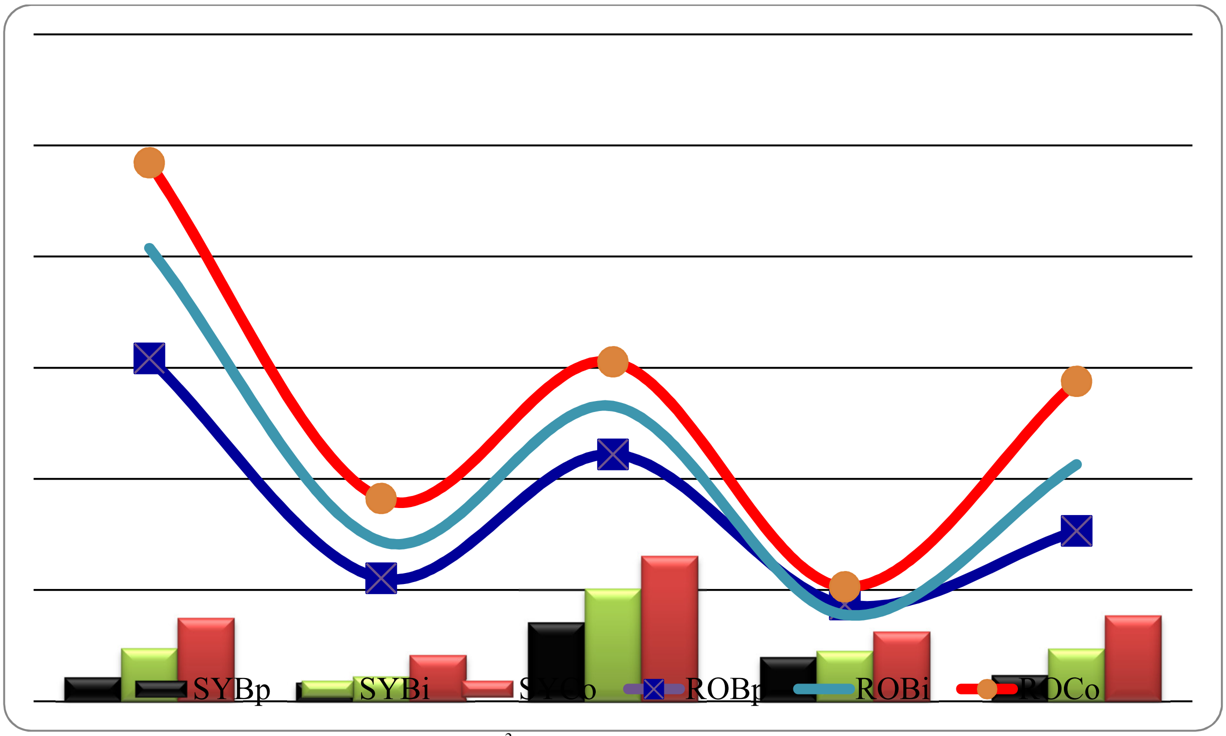
Figure 2. Field layout and randomization

3. RESULTS AND DISCUSSION

The mean soil loss and runoff volume for respective treatments are provided by the table below.

Treatment	2012	2013	2014	2015	2016	Mean
SL_{Bp}	21.50	16.75	71.01	39.67	23.53	34.49
SL_{Bi}	47.67	22.16	101.49	45.14	47.31	52.75
SL_{Co}	74.75	41.20	130.83	62.44	77.02	77.25
RO_{Bp}	308.36	110.56	222.09	86.91	153.23	176.23
RO_{Bi}	407.55	143.70	265.47	77.73	212.91	221.47
RO_{Co}	484.37	182.24	305.13	102.93	287.75	272.48

The results can be depicted by the following graph



✓ ROBi, ROBp, ROCo are runoff volumes (m^3) under biological and bio-physical conservation measures and control plot respectively**;** SYBi, SYBp, SYCo are sol loss (in ton per hectare) under biological and bio-physical conservation measures and control plot respectively.

Figure 3. Mean annual soil loss and runoff volume

One can clearly see from the result that both biological and bio-physical Soil and Water Conservation measures brought significantly lower annual runoff and soil loss when compared to the control. The lowest runoff and soil loss were recorded from bio-physical (bund stabilized by *vetiver* grass) followed by biological (*Rhodes* grass strip) soil and water conservation measures when compared to non-conserved land.

Mean soil loss recorded under bio-physical soil and water conservation measure (34.49 t/ha/year) is relatively consistent with the soil loss under the *Maybar*. Their difference may be partly due to variations in slope, rainfall, soil types, land uses, method of estimations (Wilcox *et al*., 2003), and lack of uniformity in the sizes of experimental plots (Stroosnijder *et al.*, 2014).

The average soil loss recorded under the grass strip (52.75 t/ha/year) is greater than the upper limit of *Maybar*, whereas it is lower than the lower limit of *Andit Tid* (Mitiku *et al*., 2006). The mean value of soil loss under the control (77.25 t/ha/year) is only 10 t/ha/year lower than the lower limit of the *Andit Tid*.

The soil losses as well as the runoff volume from respective treatments are in parallel throughout the whole the experimentation period. However, the variation in the trend of the consecutive year is not straight. The possible reason may be due to the amount of annual rainfall, rainfall erosivity and crop grown. Erratic rainfall is experienced at the study site. Crops are also grown in the order of pulse (soybean) – cereal (maize) rotation. The cover effect may thus the possible reason why the straight result was not observed as per for the relative effect (parallel in nature). Irrespective of its effectiveness, the *Rhodes* grass strips (biological conservation method) was easily made that it requires minimum labor input of ditch making and maintenance cost when compared to the bund stabilized by *vetiver* grass (biophysical method). The grass strip method can reduce the soil loss by about 32% than the control.

Conclusion and Recommendation

It can be concluded that soil loss (and runoff volume) from cultivated land constituted a major portion of land degradation. This land degradation processes can be minimized by establishing soil and water conservation activities, among which soil bund stabilized by *vetiver* grass is more effective method of the methods used in this study. It can prevent soil losses up to 44% than un-conserved agricultural land. One can also use grass strip method rather than employing none of the soil and water conservation activities. The grass strip (biological) method can reduce the soil loss by about 32% than the control.

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