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Evaluate the Quality of Physical Soil and Water Conservation Structures in Wyebla Watershed, Northwest Ethiopia

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Abstract
The study was carried out in the Wyebla watershed Goncha Siso Enesie *Woreda*, Northwestern Ethiopia. Similar to the other highland areas in the country Wyebla watershed is characterized, by severe soil erosion and acute water scarcity problems. Hence, the objective of the current investigation was to identify and evaluate the quality of constructed physical soil and water conservation (SWC) structures in Wyebla Watershed, Northwest Ethiopia. The quality of physical SWC structures was compared based on the package standard set by Ethiopian Ministry of Agriculture. To identify the specifications of physical SWC structures field measurements were done by transect walk. Data were analyzed using descriptive statistics. Most of the existing physical SWC structures were not constructed according to the standards. From 17 plots where SWC structures were constructed, only 20.58% (bund gradient and vertical intervals) were designed based on the package specifications. The problem was serious mainly on bund spacing and vertical intervals. Creating awareness, capacity building and application of SWC practices based on the package specifications are the critical areas looked in depth. To achieve these goals, it needs work with concerned experts in planning, selecting the desired SWC structures, implementing and maintaining of soil conservation measures to save its effect on the life of community.
Keywords: Chemo Keble, SWC, Wyebla watershed

INTRODCTION

The problem of soil degradation in Ethiopia is well established fact. The causes and consequences have been substantiated in different regions in the country (Hurni, 1988; Nyssen *et al*., 2008). The average annual rate of soil loss in the country is estimated to be 12 tons/hectare/year, and it can be even higher (300 tons/hectare/year) on steep slopes and on places where the vegetation cover is low (Abera B., 2003). According to Azene B. (1997) only 25% of the land rehabilitation targets in terms of reforestation efforts and soil conservation schemes have been accomplished and most of the physical soil conservation measures and community forest plantations were destroyed in Ethiopia. Moreover, population growth in the country leads to deforestation and the conversion of pastureland to crops leading to overstocking and further degradation. Crop residues are increasingly used for fuel rather than mulch. Dung is also used as fuel rather than manure. All these factors lead to nutrient loss and increased erosion (Jabbar *et al*., 2002).

In Ethiopia, efforts towards soil and water conservation goal were started since the mid 1970s and 80s (USAID, 2000). But the soil conservation effort has been carried out with limited success. There is less-willingness to accept and maintain the extensively introduced practices of soil conservation. Besides, soil erosion is a major contributor to the prevailing food insecurity of Ethiopia. Thus, soil conservation is vital to the achievement of food security, poverty reduction and environmental sustainability in the country (Woldeamlak B., 2007). To achieve SWC practices a collaboration of upstream and downstream stakeholders to manage water and land resources in the watershed with sustainable watershed management measures can lead to reduced soil erosion and sediment load (Awulachew S., 2010).

The study was carried out in the Wyebla watershed Goncha Siso Enesie *Woreda*, Northwestern Ethiopia. Wyebla watershed is, located in the Northwestern highlands of Ethiopia with attributes similar to the other highland areas in the country, farming practices are suffering from severe land degradation and acute water scarcity problems (Lakew D. *et al.*, 2000). Taking these problems into consideration, the *MERET* project was started to implement SWC practices in integrated watershed management based program starting 2004 to reverse the problems of the study area. The objectives of this research is, therefore, to identify and evaluate the quality of constructed physical SWC structures in Wyebla Watershed that influence sustainability of land resources and farmers' decisions on the practices of SWC structures in the study area.

MATERIALS AND METHODS

Description of the study area

The research area is located in the North Western part of Ethiopia within the highland of Amhara National Regional State (ANRS), Goncha Siso Enesie *Woreda,* Chemo Keble at Wyebla watershed. Wyebla watershed is located at 351 km North West of the capital Addis Ababa (WAO, 2009; Zemene W., 2010).

According to the simplified traditional agro-climatic classification system, which considers only altitude, the study watershed lies within *dega* (temperate) zone. The altitude range of the study watershed is from 2631-2792 masl. Agriculture is the main source of income in the area, where the farming system is characterized by small-scale production of mixed crops and livestock. Crop and livestock production dominate the farmer economy. The major crops grown are cereals (*Teff* (*Eragrostis tef*), Wheat (*Triticum aestivum*), Barley (*Hordeum vulgare*), pulses (Bean (*Vicia faba*), Field pea (*Pisum sativum*)). The livestock typical herd (flock) composition of cattle, sheep, donkey, as well as chickens and bee colony (WAO, 2012). Tree growing niches include degraded areas, gullies, farmlands and homesteads. The rarely distributed natural trees that are growing on different niches of the watershed consist of *Acacia abyssinica, Juniperus abyssinica, Rhamnus prinoides, and Croton macrostachys*. The dominant exotic tree species in the watershed are *Eucaluptus globules, Acacia saligna, Acacia deccurence,* and *Sesbania sesban.* The outputs from trees are wood for fuel, construction, farm improvements, animal fodder, income sources by selling, and environmental protection (WAO, 2012).

Description physical soil and water conservation of the watershed

Majority of SWC effort made in the study area was directed to controlling soil loss from cultivated fields. The main physical SWC structures constructed in the watershed include soil bund, water way, cut off drain, fanya juu terraces and check dams.

The soil bunds are earth embankments constructed across the slope with the ditch on their upslope side and the earth material excavated thrown down slope. A total of 496.25 ha (328 km) of soil bunds were constructed throughout the watershed within the project years. Out of 496.25 ha (328 km) only 168 ha (110.88 km) of soil bunds was constructed in self help contribution of the community (WAO, 2012). The soil bund destroyed was 28 ha (18.48 km). Cut-off drain is the same thing described as 'diversion' or 'diversion ditch' (MoA, 2005). A total of 12.36 km of cut-off drains was constructed above fields located on steep slopes, within the watershed throughout in years of the project. Out of 12.36 km only 3.36 km of cut off drain was constructed in self help contribution of the community. The cut off drain destroyed was 0.7 km (WAO, 2012). A waterway carries the run-off to rivers, reservoirs or gullies safely without creating erosion (MoA, 2005). A total of 18.28 km of water way was constructed throughout the watershed throughout in years of the project. Out of 18.25 km only 2.25 km of waterway was constructed in self help contribution of the community. The waterway destroyed was 1.5 km (WAO, 2012).

Sampling Methods and Data Collection

Data for this study were gathered from two sources: primary and secondary sources. In this research, farmers interview, field observation and measurements, were the major sources of primary data. In order to ensure the reliability and validity of the data collection, triangulation of different methods was conducted during collection of primary data. These methods include observation, focus group discussion; transect walk, and other key informants' interview. Secondary sources of information used for this study include published materials such as books, journals, annual reports, plans, official records, census records, project reports, research papers and web pages.

Evaluation of quality of physical SWC structures

The assessment targeted on the technological characteristics (design and layout) of the physical SWC structures. To evaluate the quality of the main soil conservation structures in the study area, a careful investigation was conducted on the three parts of watershed along the transect line. The existing physical SWC structures in the study area were compared based on the packages (MoA, 2001; BoA, 2013) Table 1.

Table 1. Spacing of bunds expressed in vertical interval (VI) and horizontal interval (HI)

Slope in (%)	>75cm (soil depth)		50-75cm (soil depth)		25-50cm (soil depth)	
	VI (m)	HI (m)	VI (m)	HI (m)	VI (m)	HI (m)
3	1	33				
4	1	25				
5	1	20	0.7	15	0.5	10
6	1	17	0.7	12	0.6	10
7	1	14	0.8	12	0.7	10
8	1	12	0.8	10	0.7	9
9	1	11	0.9	10	0.8	9
10	1	10	0.9	9	0.8	8
11	1.1	10	1	9	0.9	8
12	1.1	9	1	8	0.9	8
13	1.2	9	1.1	8	1	8
14	1.2	8	1.1	8	1	7
15	1.2	8	1.1	7	1	7
16	1.3	8	1.1	7	1	6
17	1.3	8	1.2	7	1.1	6
18	1.3	7	1.2	7	1.1	6
19	1.3	7	1.2	6	1.1	6
20	1.4	7	1.2	6	1.1	6

Source: MoA, (2001); BoA, (2013)

Data Analysis

Depending on the type of information collected from the field, different data analysis methods were applied. Data collected was organized, analyzed and summarized using Microsoft excel, and descriptive statistical analysis methods. Finally the statistical results obtained from different primary sources both qualitative and quantitative analysis of the data was subjected to presentation in the form of text, tables, and pictures.

RESULTS AND DISCUSSION

Evaluation Quality of Physical Soil Conservation Structures

To evaluate the quality of the main soil conservation structures in the study area, a careful investigation was conducted on the three parts of watershed along the transect line. The major physical SWC structures were found to be soil bund, water way, cut of drain and check dams. These structures have mainly constructed in the past ten years. In the first three years, main physical SWC structures and plantations were done and, on the rest maintenance works were implemented.

Bund spacing, bund gradient and field slopes were measured to check the quality of physical SWC structures Table 2. Other physical SWC structures design specifications like bund cross sectional areas (bund embankment height, embankment top and bottom width, channel depth and width) did not include in the field survey because these specifications does not easily recognized since the SWC structures were constructed in the past 10 years.

From 17 plots where SWC structures were constructed only 7 out of 34 spots (20.58%) (bund gradient, bund horizontal interval and vertical intervals) were done based on the packages. The rest 27 out of 34 spots were not done based on the packages. The problem was serious mainly on bund vertical intervals, where there was not observed any similarity between existing soil and water conservation structures and the recommended one Table 2. As per discussion with the farmers, the main reason for the failure to achieve SWC structures based on the package is knowledge and skill on SWC practices. This was not only for farmers but also for DAs. Most farmers perceived that constructing bunds in narrow spacing may create difficulty in plowing activities and reduces farm size at the same time needs much labor forces to implement. From field observation along the transect line indicated that almost all farmers were using traditional drainage ditches between the bunds for *teff* cultivated fields. The reason why they used this was to protect removal of *teff* seed and seedling by sheet erosion and to lead sowing and cultivation activities. This structure was mainly the results of wide spacing between bunds. This type of conservation measure was out of the packages which had negative impact on erosion control, because this drainage ditches have on average high slope gradient (3-6%) which leads to erosion along traditional drainage ditches and create much siltation on the bunds Fig. 1. Gizaw D. (2010) indicated that farmers have constructed a small drainage ditch across the slope to protect the lower field from concentrated runoff during heavy storms. The farmer has to construct these drainage ditches each year randomly on the plot. It is obvious that sediments eroded from ditches and accumulated down slope were common indicators of erosion on farmer's field. In contrary, study done by Assefa D. *et al*. (2009) cultural ditches currently implemented by farmers are generally effective and should be an integral part of any soil and water management practices proposed by soil conservation designers.

Table2. Evaluation of current SWC structures against package.

Plot No	Vertical Interval		Bund Gradient %		Number of dismantled Spots (3)
	Recommended	Existing	Recommended	Existing	
1	0.9	2.8	0.5-1	1	1
2	1	2.52	0.5-1	1.2	2
3	1	0.63	0.5-1	1.5	2
4	1	2.4	0.5-1	1.5	2
5	1.1	2.9375	0.5-1	1.0	1
6	1.1	1.82	0.5-1	1.5	2
7	1	1.254	0.5-1	3	2
8	1	1.375	0.5-1	0.25	2
9	1	1.40	0.5-1	1	1
10	1	1.55	0.5-1	0	2
11	1.1	2.0125	0.5-1	1.2	2
12	1	1.20	0.5-1	1	1
13	1	0.63	0.5-1	5	2
14	1	0.8	0.5-1	1	2
15	1	1.70	0.5-1	2	1
16	1	1.5	0.5-1	1	1
17	1	2.375	0.5-1	1	1
	Mean 1.01	1.70	0.75	1.42	
	Number of dismantled spots	All (17)		10	27 out of 34

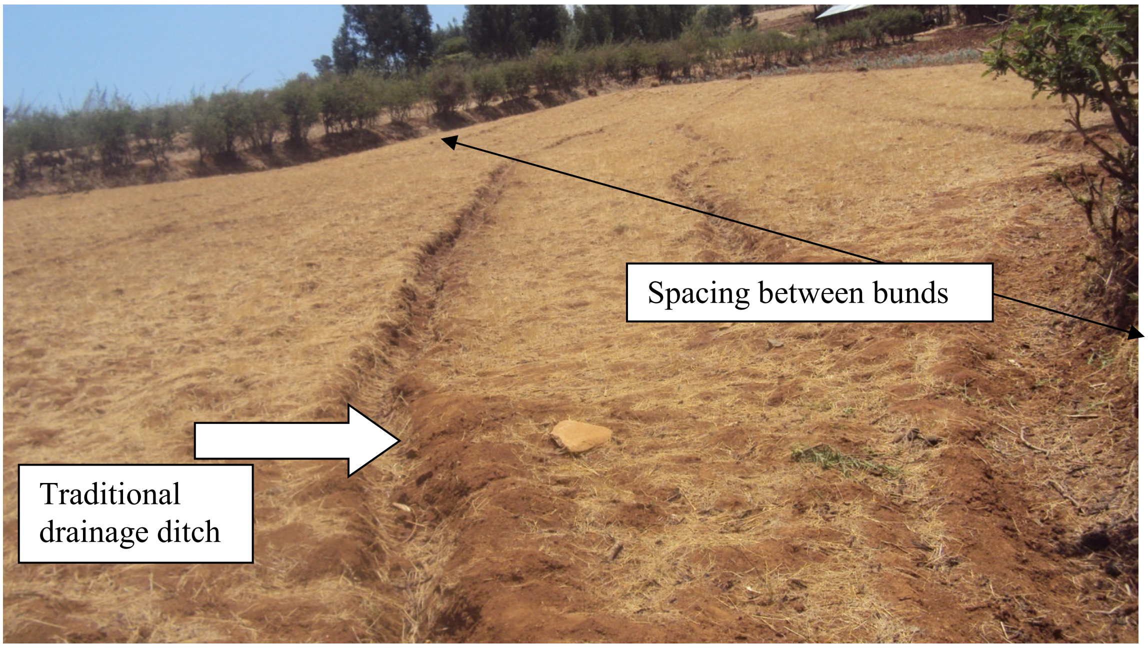

Figure 1. Traditional drainage ditches constructed between two bunds.

Spacing of bunds

In principle, the spacing should decrease when slope gradient increases (Gizaw D. *et al*., 2009). However, bunds implemented by the farmers had shown in Table2, did not correctly applied the principle set in the package. The spacing of the bund was determined by individual interest (farmers and expert). According to WTCER (2011) the basic principles for determining the spacing of bunds are: seepage zone below the upper bund should meet the saturation zone of lower bund, the bunds should check the surface runoff at the point where flow attains an erosive velocity and the bund should not cause inconvenience in agricultural operations. However, spacing of bunds (i.e. vertical interval between bunds) is decided based on the land slope, infiltration rate of the soil and the rainfall of the area. According to the measurement conducted, VI = 1.70 ± 0.71 m.

Assessment and evaluation of most common types of physical SWC measures

In complementary to the assessment and evaluation of erosion problems at field and catchment scales, assessing the performance of existing SWC structures would give the opportunity to identify the limitations and provide hint for improvements of SWC measures. The assessment targeted on the technological characteristics (design and layout) of the physical SWC structures. Soil bund were widely practiced and distributed almost all over the cultivated plots in the study watershed. Nearly 76.4% household farmers had experienced in supporting the physical SWC structures with biological conservation measures like *Sesbania sesban* Fig.2, which give multiple purposes for community. As indicated in Fig.2, bunds did not make bench terrace even if they were aged (> 6 years). This is because of wide spacing of bunds and lack of timely maintenances. Along the transect line observation, some bund structures were silted up and damaged due to runoff overtopping the bunds, and improper tillage underneath the bunds. There was no common and standard bund layout and design for the same slope and soil conditions.

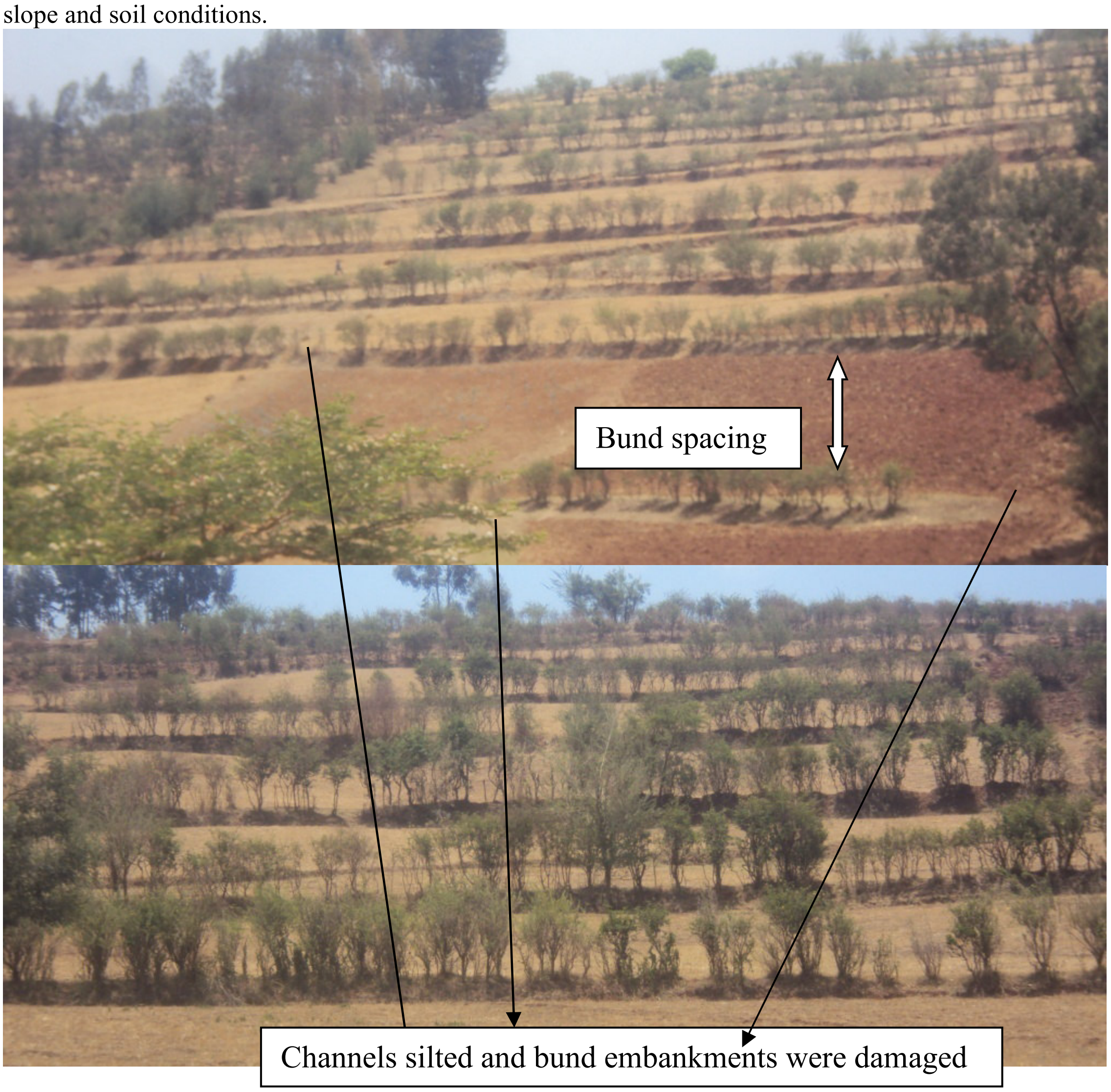

Figure 2. Physical SWC structures supported by vegetative measures.

Gully control measure

From households' survey results, 36.8% of the farmers land was affected by gully erosion. Gully erosion is one of the forms accelerating soil erosion (Gang *et al*., 2009). Soil loss rates by gully erosion represent more than half of the total sediment yield caused by water erosion (Valentin *et al*., 2005). From the field observation, the main causes of gully in the study area were over grazing, poor design of physical SWC structures, deforestation, and continuous use of arable land and cattle tracks lines Fig.3, According to Getachew F. (2012) the cause of gully formation are soil characteristics, human activities, and natural factors. Gully formation can be also stopped by disturbed concentrated run off coming from the roads, increasing vegetation cover and reducing over grazing.

Figure 3. Gully erosions formed in different sites of the watershed.

In the study area, several gully rehabilitation measure were implemented in the past 10 years Fig.4, though restoring gullies is more complicated and expensive. Once gullies are formed, large amounts of soil from surface and subsurface layers have been already lost (Blanco and Rattan, 2008). Gully prevention measures in the study site includes soil managements, agronomic practices, correctly designed and constructed physical SWC measures in the watershed base which reduce run off development. When gullies were already formed, there were two options of control are; to reclaim the gullies to conditions similar to the uneroded portions of the field and managing the existing gullies by stabilizing the gully head, bed and sides and reducing their expansion

Figure 4. Different types of water harvesting structures under area closure reduce gully development in the lower catchment.

Almost all gully control measures in the study area were effective to arrest loss of soil and protect development of new gullies Fig.5 & 6. This is because check dams and sediment storage dams (SSDs) where constructed based on the package except some check dams.


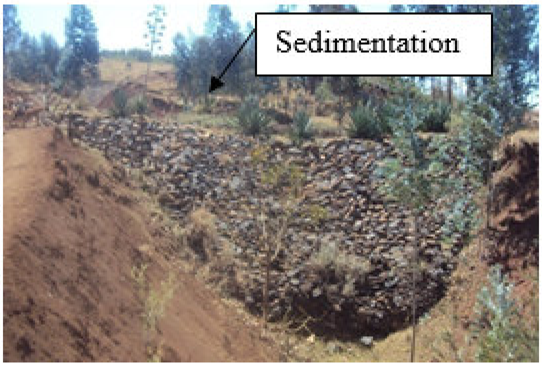

Figure 5. Farmers fetch water from SSD. Figure 6. SSD constructed on a large gully

From 13 sampled check dams 11(84.6%) of the average vertical interval between check dams is not more than 1m and side keys and spill ways also designed based on the package specifications. As a result streams were developed in restored gullies where watershed communities used for irrigation purpose in dry season Fig.5. In some parts of the watershed gully rehabilitation activities were not effective Fig. 7. The failures of these check dams were poor design lay out and specifications selection. The height of check dams was 1 m but the vertical interval was 2 m. This shows that the spacing between two successive check dams was greater than the recommended one (1 m). From the field survey data record the average gully width, depth and catchment areas are 5m, 4m and 9ha, respectively. In these gully dimensions stone check dams are not recommended. Rather these types of check dams were used for small gullies which have ≤2.5 m depth (BoA, 2005). Even though gabion checks dams were used, it did not achieve the desired goal. The reason is that the design lay out and specifications did not consider the run off volume resulted from above catchment Fig. 7.

Figure 7. Ineffective stone and gabion check dams on large gullies.

CONCLUSIONS

The qualities of SWCs were assessed and the result revealed that spacing and vertical interval between successive structures showed difference between existing and recommended physical SWC structures. The implication for this is that desired objectives of these SWCs cannot be achieved; the time to form soil bunds to bench terraces will be long and their longevity will be shortened. Along the transect line observation, some bund structures were silted up and damaged due to runoff overtopping the bunds, and improper tillage underneath the bunds. There was no standard bund layout and design for the same slope and soil conditions. Similarly, steep gradient traditional drainage ditches between bunds for *teff* cultivated fields affect the sustainability of bunds and erosion control processes. Moreover, the process of land degradation can't be stopped with such types of poor quality structures. Even if in the Wyebla watershed, gully erosion affects the livelihood of community, there was good back ground to restore these areas.

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