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Evaluation of brush wood with stone check dam on gully rehabilitation in Ethiopia

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ABSTRACT

Gullies are common features throughout the Ethiopian Highlands. Induced environmental degradation comprises not only the loss of soil volume and of arable lands but also the triggering of landslides or off-site sedimentation problems. This experiment was initiated with the aim of evaluating the effect of brush (bamboo) wood with stone check dam on soil and water conservation (gully rehabilitation) at Benishangulgumuz region of Assosa zone (Assosa district of selga-19 for two consecutive research years (2013/14-2014/15) on farm land. The gully site was selected purposively based on the prevalence of gully erosion. Biophysical and socioeconomic data were collected from the gully and participant farmers to evaluate the effectiveness of the measures. The potential of the check dam to conserve the soil was evaluated by using the pin installed in front the check dam to observe the change of gully depth, cross sectional area and soil loss data were collected. A total of 22 households were sampled to assess the perception, acceptance and adoption level of the farmers using simple random sampling technique. Result indicates that the gully depth and volume of soil loss were reduced from 0.94m to 0.58m and volume of soil loss from 468 ton/ha/yr to 204 ton/ha/y. The interviewed farmers response also indicated that all (100%) of them were mentioned the presence and severity of soil erosion on their farm land and which is increasing from time to time in alarming rate and where all of the farmers mentioned loss of fertile top soil and in turn yield reduction as its integral effect. 95.5% of the farmers were confident enough to rehabilitate the gully using bamboo with stone check dam by supplementing with other biological measures and all (100%) of the farmers ratified the effectiveness of the measures to rehabilitate the gully and willing to implement on their farm land thereby to disseminate the technology to non-participant farmers.

Key Words: *Gully, Soil loss, Dam and Brush wood*

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I. Introduction

Land degradation, comprising degradation of the natural vegetation cover, soil erosion, loss of soil fertility and moisture stress is a well known problem in Ethiopian highlands and in developing countries (Herweg and Stillhardt, 1999; Siddique et al., 2014). Soil loss, land degradation, particularly by water erosion, is an important factor in both the long term decline and the seasonal reduction in food crop production (FAO, 1986; Siddique et. al., 2017). Soil erosion in Ethiopian Highlands degrades the soil resources on which agricultural production are based (Hurni, 1986; Nyssen, 1995). This threat stems from the depletion and degradation of the vegetation cover of the country, especially forests, and exploitative farming practices. Gullies are common features throughout the Ethiopian Highlands. Induced environmental degradation comprises not only the loss of soil volume and of arable lands but also the triggering of landslides (Nyssen et al., 2002) or off-site sedimentation problems. The phenomenon of gully development is not restricted to Highlands of Ethiopia but seems to be a phenomenon on sub-continental scale in Africa (Moeyersons, 2001). Recently, EIAR (Ethiopian Institute of Agricultural Research) financed soil and water management and or conservation research has been initiated by (Menna et al., 2007); and in this work an endeavor has been made to identify and characterize indigenous soil and water conservation materials and practices in the Metekel zone with the aim of making recommendations based on the research findings and launching further research interventions. In the assessment, it has been found that farmers in the area have various agronomic practices like (shenna, intercropping, crop rotation); and vegetative materials (Nechsar, Dagalla, kollasembelet and others) used for soil and water conservation and gully rehabilitation, which could further be improved and or augmented with other practices for gully rehabilitation (brush wood check dams) and materials for soil conservation on farm lands such as Vetiver grass (*Vetiver zizanoides*) hedges. Vetiver occurs in many countries throughout the world. It is introduced to Ethiopia in the 1960's. Vetiveris not site specific, it grows in a wide variety of soils and climatic conditions, it is easy to establish, it is not time consuming, a larger kilometer can be established within a season, very effective and cheaper, it can with stand livestock browsing and trampling. It is promoted as a strategic soil conservation measure in some parts of the country in an effort to halt soil erosion and land degradation (Tessema Chekun, ND). Grass is used for rehabilitation of gullies, road cuts and drain stabilization, river bank protection, watershed rehabilitation for dam side protection, forage, wet land protection and income generation for schools (Mekonnen, 2008). Therefore, this experiment was initiated with the aim of enhancing the awareness of the farming communities and evaluating the effect of different physical and biological measures of gully rehabilitation. The study was conducted to evaluate the effect of brush wood with stone check dam on soil conservation and to create awareness among the farmers on gully rehabilitation.

II. Materials and Methods

The study was conducted at the Assosa Agricultural Research Center (ASARC), which is located in Assosa District at Benishangul-Gumuz Regional State (BGRS). The ASARC is located in the western part of Ethiopia from 10º 01' 25'' to 10º 02' 50'' north latitude and from 34º 33' 50'' to 34º 34' 35'' east longitude. The study area covers a total land area of 202.5 ha with geologyof Tarmabe basalt, sometimes porphyritic of the Miocene to Pliocene period. The Assosa District is characterized by hot to warm moist lowland plain with uni-modal rainfall pattern. The rainy season starts at the early May and lasts at the end of October with maximum rainfall in the months of June, July and August. Total annual average (2000-2007) rainfall is 1316 mm. Annual mean minimum and mean maximum temperatures of the District for the periods from 2000 to 2008 were 16.75 and 27.92 ^{0}C respectively. Soil type of the study area was characterized as Nitisol.

The study area was selected purposively with different stakeholders (Farmers, kebele administration, DAs and wereda natural resource experts) based on prevalence of gully erosion and accessibility as a criteria for site selection. A group of farmers which has 10-15 members were established to handle the gully research experiment. Training programs were organized for different stakeholders prior to start the experiment oncauses of gully formation, management/rehabilitation of gullies and utilization of gullies. The gully was treated with bamboo with stone check dams, and different biological materials depending on the agro ecology and accessibility of the selected sites.

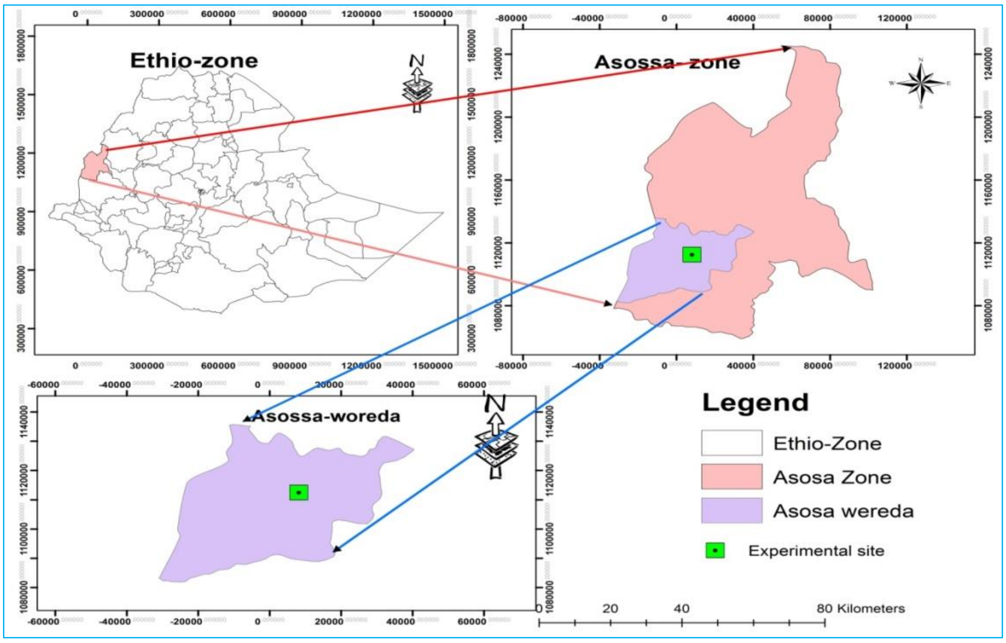

Figure 01. Location map of experimental site.

Width and depth of the check dam were decided based on the types of gullies that exist in the area on the first year of the activity. Gully cross section area, gully depth, and width were measured before and after the implementation of the gully rehabilitation measures to evaluate and determine the rate of soil loss. Socioeconomic status of the participant farmers such as gender, wealth, age, education, perception of land degradation and mitigation solutions were collected through structured questioner.

Soil sampling and analysis: Composite soil samples were collected before and after the experimentfrom the gully site. Replicated soil samples from the upper, middle and lower parts of the hedgerows were collected at the end of the experiment for soil pH, organic C, total N, available P and exchangeable K determination. Prior to the analysis, the soil samples collected from were air dried, ground and sieved to pass through 2 mm size sieve in preparation for laboratory analysis of most soil physical and chemical properties. Soil samples were further sieved to pass through a 0.5 mm size sieve for the analysis of total nitrogen. pH of the soil was measured potentiometrically using a digital pH meter in the supernatant suspension of 1:2.5 soil to water ratio. Organic carbon was determined following the Walkley-Black wet digestion method whereas the Kjeldahl procedure was followed for the determination of total nitrogen. Available phosphorus was determined by the Olsen procedure. Soil samples were shaken with 0.5M sodium bicarbonate at nearly constant pH of 8.5 in 1:20 of soil to solution ratio for half an hour and the extracts were obtained by filtering the suspension.

Data were systematically coded and analyzed using descriptive statistics using Statistical Package for Social Sciences (SPSS) version 20.0 for the household survey.

III. Results and Discussion

Rainfall distribution

Amount and distribution of precipitation that causes runoff varied during two year of study from 2013 to 2014. Figure 02 shows the monthly distribution of rainfall at the experimental sites. During the season annual rainfall that causes runoff in 2013 and 2014 was 1161.8, and 877.8 mm respectively.

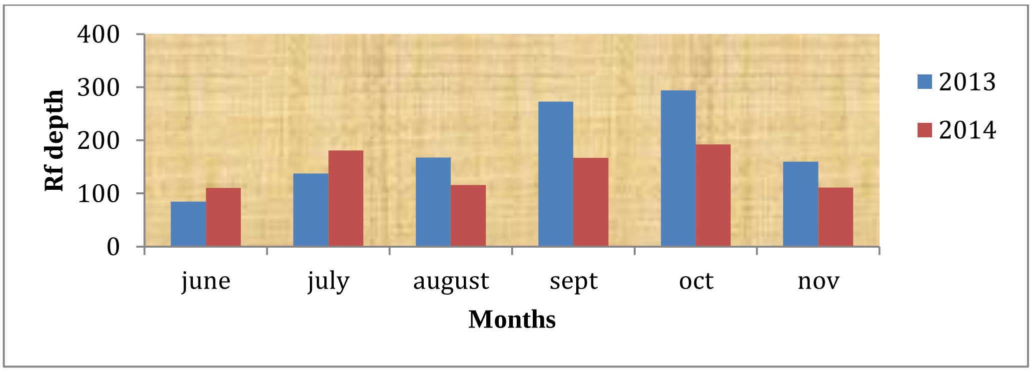

Figure 02. Rainfall distribution (in mm).

Gully depth

Change in depth of the gully is the key parameter to evaluate the efficiency of gully rehabilitation measure. Data of depth of the gully were collected monthly in the rainy seasons of 2005/06 and 2006/07.

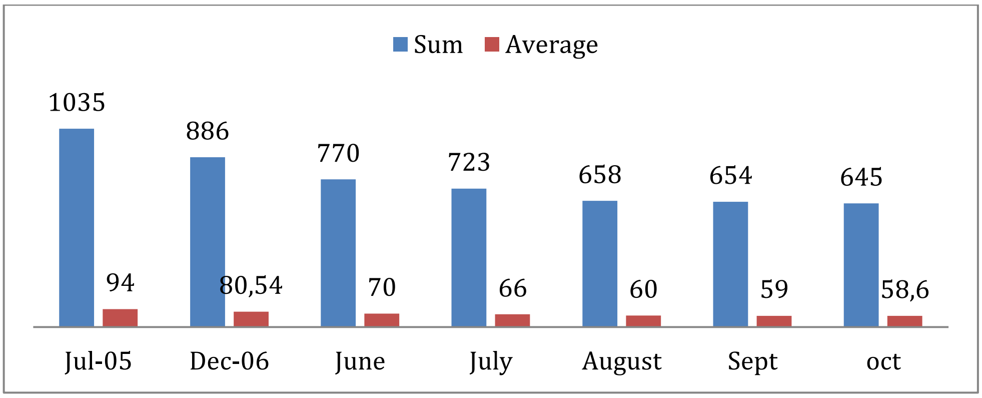

Figure 03. Average and sum of gully depth at selga-19 since 2005/06.

Intervention of brush wood with stone check dam had brought great change. Initial average depth of the gully before interventionwas 0.94m and reduced to 0.805m at the end (after intervention) of the rainy season of first year (December 2006). On the second research year, the structure had brought the change from 0.805m to 0.58m. Totally, using brush wood with stone check dam had reduced the depth of the gully from 0.94m to 0.58m since its intervention.

Cross sectional area of gully

Cross sectional area is also another key parameter to determine the amount of soil loss from the gully. Its length was 253m from head to base with drainage area of 2.5 ha. Bulk density of this gully was 1.08 ton/m^3.

Table 01. Cross sectional area and soil loss in average at selga-19

Collected Parameters	One year after impl. (June 2005)	After impl. (Dece 2006)	At oct-2007	Difference
Cross sectional area	4m^2	2.4m^2	1.9 m^2	2.1
Volume of soil loss	886m^3	607m^3/yr	480.7 m^3/yr	471.8 m^3/yr
Volume of soil loss per meter equiv.	0.04m^3/m^2	0.03m^3/m^2/yr	0.02 m^3/m^2/yr	0.02m^3/m^2/yr
Volume of soil loss in tone	468 ton/ha/yr	351 ton/ha/yr	205ton/ha/yr	200.32ton/ha/yr

Initial volume of soil lost from the gully before implementing the structure was 886 m^3 and reduced to 607 m^3/yrand 480.7 m^3/yr at the end of first and second year respectively. As the above table shows, the introduced technology reduced the cross sectional area and soil loss of the gully by more than half, which shows thesoil and water conservation potential of locally available materials for gully rehabilitation.

Table 02. Chemical properties of soil at selga-19

Sites	Parameters					
Selga-19	PH	OC%	N%	P	K	CEC
At first year	6.96	3.6	0.336	10.43	1.7185	21.6
At end of second year	6.31	1.24	0.168	3.82	0.4	24.02

Soil sample was collected from gully channel at the depths of 0-15cm to evaluate the effect of physical and biological gully rehabilitation methods on soil fertility improvement and reduction of soil loss. As the above table shows, there was reduction of all parameters except CEC and K in the gully channel, which shows the poor fertility status of deposited soil particle at second year. Eroded and deposited soil in front of the structure was poor in nutrient content than that of first year soil particle because of removal of fertile top soil by continuous water erosion. This result showed that declining of the soil fertility status in the drainage basin due to continuous soil erosion over time.

Perception, acceptance and adoption of farmer

Table 03. Farmer perception on soil erosion

No.	Questions for perception evaluation	Answer of respondents (%)	
		Yes	No
1	Problem of soil erosion on their farm land	100	
2.	Can soil erosion be reduced	86.4	13.6
3.	Have you ever discussed and draw potential solution for soil erosion problem of your area	36.4	63.6
4.	Do you know about SWC technologies before	22.7	77.3
5.	Have you ever participated on demonstration and field days of SWC technologies before		100

No	Perception parameters	Respondents (%)
1.	Severity of soil erosion on their farm land	
	Severe	13.6
	Moderate	86.4
	Minor	-
2.	Water erosion type on their farmland	
	Sheet	18.2
	Rill	77.3
	Gully	4.5
3.	Soil erosion change over time	
	Highest	77.2
	Medium	9.1
	Low	13.6
4.	What the effect of soil erosion on your farm land	
	Loss of fertile top soil	100
	Yield reduction	100
5.	What the impact rate of soil erosion on crop production	
	Large decrease	45.5
	Moderate decrease	36.4
	Moderate increase	13.6
	Large increase	4.5

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Farmers were interviewed with the aim of assessing the perception of farmers on presence of soil erosion, severity, erosion type, effect and its rate of change over time on agricultural land. Based on this, all of the farmers were mentioned the presence of soil erosion problem on their agricultural land whereas 86.4% of the farmers were confident that the problem can be reduced by using different soil and water conservation technologies where as 13.6% of them were not. Most of the farmers were not ever discussed, know, and participated on demonstration of soil and water conservation before. As the result of the interview showed, 77.3%, 18.2%, and 4.5% of the farmers were affected by rill, sheet and gully erosion respectively. But, the rate of soil erosion is increasing over time and affecting the farmers by eroding the fertile top soil there by reducing their productivity.

Farmer acceptance

Table 04. Farmer acceptance on soil erosion

No.	Questions for acceptance evaluation	Answer of respondents (%)	
		Yes	No
1	Did you know/used bamboo with stone check dam to manage gully before	22.7	77.3
2.	Is bamboo with stone check dam is effective in arresting soil erosion	95.5	4.5
3.	Do you believe that bamboo with stone check dam has the potential to improve gully productivity	95.5	4.5

Acceptance of bamboo with stone check dam to manage gully and its potential on soil and water conservation hadalso been assessed by interviewing the farmers. Most of the farmers (77.3%) didn't ever usethe technology where only 29.4 % of them had its slight information prior to the experiment. After intervention, all of the farmers ratified the effectiveness of the check dam on arresting soil erosion and 95.5% of the farmers believe that thegullied land can be changed to productive land by supplementing the physical structure/check dam with different biological measures.

Farmers adoption

Table 05. Farmers adoption on soil erosion

No.	Questions for adoption evaluation	Answer of respondents (%)	
		Yes	No
1	Do you have the plan to manage and maintain the check dam	100	
2.	Do you have plan/intention to implement the check dam on the rest of your plots	100	
3.	Do you believe that implementing SWC technology is the farmers responsibility	100	
4.	Should the farmers be paid for implementing and maintaining of SWC in their farms	18.2	81.8

It is obvious that the end users of agricultural research are the farmers and other stake holders. Based on this, the willingness of the farmers to adopt and disseminate bamboo with stone check dam technology to manage gully had also been assessed and all of the farmers had the willing to implement on the rest of their plot, to maintain the check damand believe implementing different soil and water conservation as their responsibility. But 18.2% of the farmers believe as they should be paid for implementing and maintaining soil and water conservation which was related with the land policy of Ethiopia (the land belongs to the government) where as 81.8% of them had the believe of government shouldn't pay for the farmers.

Socioeconomics of households

Total of participant households in the study were 17 and selected to collect qualitative data of farmer perception on potential of brush wood and stone check dam grass on soil and water conservation. All participant farmers were male with the mean age of 44 year ranging from 22 to 66 years. The educational status of the farmer is the key factor for good understanding of their environment and by considering this, education level of the participant farmers were collected. As the study indicates, 50% of the farmers were illiterate whereas 36.4 and 13.6% of the farmers have attended their primary and secondary education respectively. As the study reveals, half of participant farmers were non-educated which may in turn affect the awareness of the community on soil erosion and its effect.

IV. Conclusion

Results obtained from this study indicated the conservation/rehabilitation potential of using bamboo with stone check dam to manage gully. Beside this, the study also created awareness and motivation among farmers about gully and its control. Fertility status of deposited soil was decreased because of continuous removal fertile soil layer by water erosion from the farm land. This can be improved by other fertility enhancement methods especially organic fertility improvement measures on the upstream and within the drainage area of the gully to improve both soil fertility and erosion control. Organic soil fertility enhancement methods are also used to improve the structure/aggregation of soil and increase the permeability of the soil thereby reduce the runoff generation within the drainage. Thus, farmers and other stakeholders should have to use locally available materials which are cheap and effective to rehabilitate gully. This brought radical change for both gully depth and cross sectional area. Use and dissemination of locally available materials for gully rehabilitation technology is another assignment of participant farmer and expert to non-participant farmer.

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