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Full Length Research

Community Based Participatory Gully Rehabilitation with Double Post Brush Wood Check Dams and Vegetative Resources Dangur District, Northwestern Ethiopia

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The research was conducted by Pawe Agricultural Research Center (PARC) in 2010- 2013 with the objective of to evaluate the effect of double posts brush wood check dam, and biological resources measures for gully rehabilitation in Dangur district, Northwestern Ethiopia. The study area was selected severity of gully formed areas and potentials of actively involvement of community and stakeholders. Before gully land rehabilitation, gully longitudinal profiles were measured. A formal survey was carried out for questionnaires total of 76 households' selected simple random sampling techniques to measure understanding community awareness gully land rehabilitation, gully measurement and empirical formula techniques were employed. The results indicated that the major causes of gully formation were improper drainage during road construction (40.8%), inappropriate farming and land use system (36.8%), deforestation (17.1%), trails and foot paths (3.9.%) and overgrazing (1.3%), respectively. Gully rehabilitation control and development program in forth coming highly acceptable (90%) followed by modern acceptable (84.2%) and acceptable 14.5%, respectively. Before gully rehabilitation (2010) necessary gully profile dimension measurements (slope, depth, top and bottom width, vertical interval and commutative) were in average 5%, 1.86m, 5.80m, 2.23m, 0.729m and17.50m, respectively. After treated (2013) its profile (slope, depth, top and bottom width, vertical interval and commutative) were condensed into 4%, 1.47m, 6.11m, 1.41m, 0.623m and 14.94m respectively. In 2010 the total volume of gully was 2995.5m^3 while after rehabilitated (2013) it was reduced into 1,479.9m^3 which was accumulated 1,515.6m$^{3.}$ Eventually there can be concluded that the damages gullied land can be restored with integration of communities and stockholders which increases production and productivity of environment. Poor gully maintenance, improper of spillway, apron and Improper spacing of check-dams and Poor integration between physical and biological measures installation of check-dams which is related to lack of keying the check-dam to the floor and sidewalls of the gully should be avoided.

Keywords: Gully, Check dam, participatory, vegetative measures

INTRODUCTION

In Ethiopia, gullies can be found everywhere in all climatic, soil, physiographic, lithological and sub-stratum settings (Billi and Dramis, 2002; Ayele et al., 2015; Obsa et al.,2017). The Soil Conservation Research Project (SCRP) research stations confirmed that soil erosion increases normal as well as anthropological factors that research have been conducted Ethiopia agro-ecology representative catchment (Hurni, 1986; Nyssen, 1995;Mitiku et al., 2006). Overgrazing (Valentin et al.,2005), road construction and building activities with inadequate drainage systems and insufficient road-ditch capacity (Nyssen et al*.,* 2002;Belayneh et al., 2014) constitute major factors of gully formation.

Studies have shown that over the past five decades, gullying in Ethiopia has been widespread and has become more severe (Nyssen et al., 2007; Tebebu, 2009; Tebebu et al., 2010. Gully occurs after the watershed is altered for example by cutting down the forest and replacing it by agricultural land (Tebebuet al*.,* 2010; Tilahun et al., 2013; Ayele et al., 2014).This results in additional interflow and runoff that the existing drainage network cannot handle and a new equilibrium is established to carry of this water (Kleidon et al. 2013).

Gully erosion direct impacts on biophysical effects negatively affect the community's socio-Economic activities (Poessen et al*.,* 2003; Frankl et al., 2012), for instance, contribution of gully erosion to the overall soil loss in the northern highlands of Ethiopia was measured to be 33 to 55%, which equals 4.7-12.1 t $ha^{-1}y^{-1}$ (Nyssen, 2001).The soil and water conservation practices so far on the Ethiopian have usually targeted the undulating slope areas through a top-down approach (Bewket and Sterk, 2002), not giving enough attention to gullies. For example, the new soil and water conservation campaign initiated by the government in 2012 focused only on putting bundson the hill slopes and cultivated lands. However, gully erosion removed soil with an equivalent depth of 4 cm per year over these highlands (Tilahun et al., 2013; Tebebu et al., 2010).

The check dams are used to prevent the development of permanent gullies in agricultural lands (Nyssen et al. 2004a). However, everywhere aren't these conservation measures adopted by farmers, even though they prove to be effective. Another research to gully erosion that is carried out is by (Moges et al. 2008) in the Umbulo catchment in Southern Ethiopia also confirm that conservation measures are not adopted for gully rehabilitation. The study of gully erosion has to date been neglected due to the difficulties of investigation and of prediction (Valentim et al., 2005). However, indifferent countries research have been carried out as seen in the last international conferences held in Leuven (Belgium, 2000), Chengdu (China, 2002), Oxford (USA, 2004), Pamplona (Spain, 2007) and Lublin (Poland, 2010) 6^{th} International Symposium on Gully Erosion in a Changing World (6th ISGE, 2013). Nevertheless, in recent years, this erosion form has attracted increasing interest in gully erosion studies. The purpose of this study was to evaluate the effect of gully rehabilitation with double post brush wood check dam and biological resources in Dangur district, north western Ethiopia.

METHODS AND MATERIALS

Description of the study area

The study was conducted in Beles village, Dangur District, Metekel Zone, Benishagul Gumuz National Regional State, in the lowlands of the northwestern part of the Ethiopia between2010 -2013 fiscal year that is geographically located between 11.27^0 and 11.23^0 N latitude and 036^0 15.01^0 and 36.26^0 E longitude with an altitude range 1115-1,219meter above sea level (Figure 01). The mean annual rainfall of the study area is between of 900mm-1500 mm. It has unimodal rainfall distribution pattern, with mean minimum and maximum annually temperature ranging from 28^0cto 38^0c, respectively. The area has warm-h locally known as worm Kola-agro-climatic zone (Engda, 2000).The topography of the study is characterized as slightly undulating from hill-tops towards rivers with its slope ranges from 3% to 8%. Most of the farmlands are relatively gentle and flat with an average slope of 5%.

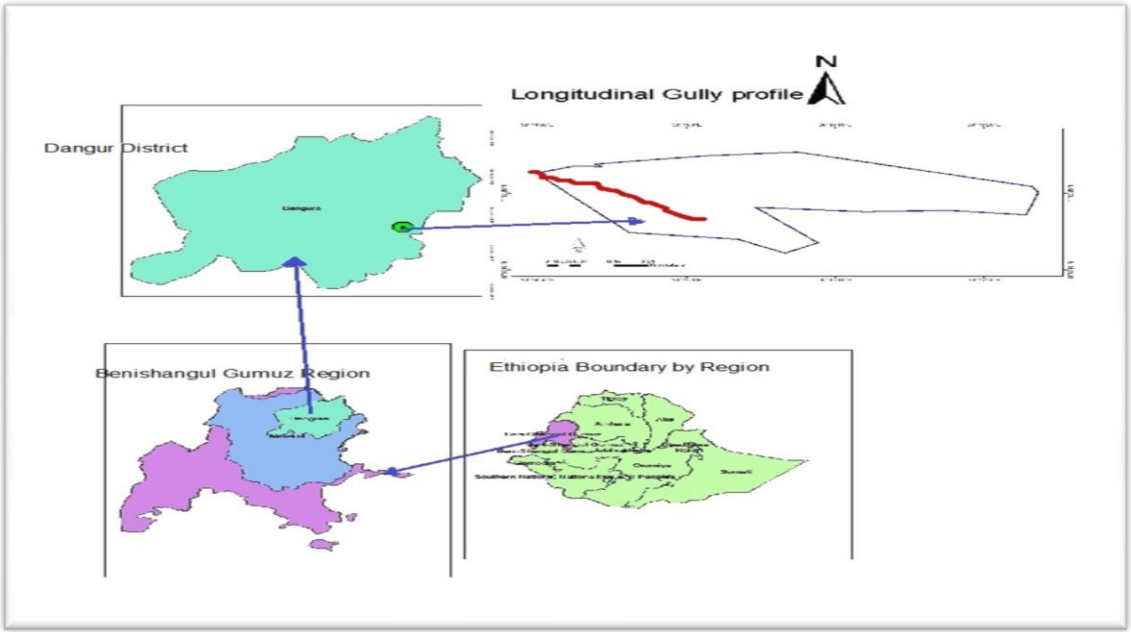

Figure 1: Location map of the study area.

Data Collection and Statistical Analysis

Primarily, the study area was selected purposively on the basis of the availability the gully severity formed areas and its potentials and significance to participate the surrounding community. The gullied sitewas selected together with the community representative, Development Agents' Agricultural Development experts and researchers. After decided to rehabilitate the gullied land, longitudinal profile gully parameters were collected using clinometer, GPS, measuring tape, surveying rods and water level were used to measure gullied land slope, location, distance, depth and keep level, respectively to determined gullied land volume and cross sectional area dimensions before rehabilitation it.

Double wood posts check dams were preferred than others check dams for gully rehabilitation because of the availability of brush wood materials in the studyarea.The vegetative materials were Vetiver grass (*Vetiveriazizanioides*) and low land bamboo (*Oxytenantheraabyssinica*) for stabilized gully walls and bed. Beforere habilitation, the gullied and volume, top and bottom width, slope, vertical and horizontal distance, ground length and depth parameters were taken by measuring replicated from the gullied land gully systems a field and survey was carried out in 2010.These measurements were averaged to get an estimation of the volume using the following equation:

V=L*A ………………………………………………………………………………………….. (1)

WhereV, volume gullied land L, is the length of the gully in meters and A is the cross sectional area of the gully in m^2.

According to FAO (1986) the numbers of check dams were determined by measuring the average gully channel gradient, horizontal distance and vertical distance the number of check dams for each portion of the main gully channel wascalculated.

N.O.C.C= (a-b)/h………………………………………………………………………………………….. (2)

a: The total vertical distance is calculated according to the average gully channel gradient and the horizontal distance between the first and last check dam in that portion of the gully bed.

b: The total vertical distance is calculated according to the compensation gradient and horizontal distance between the first and last check dam in that portion of the gully bed (compensation gradient.

h: The average effective height of the check dams, excluding foundation, to be constructed in that portion of the gully bed.

Table 1: The gullies longitudinal profile before rehabilitation to determine number of check dams

Series No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Shoot point	AB	BC	CD	DE	EF	FG	GH	HI	IJ	JK	KL	LM	MN	NO	OP	QR	RS	ST	TU	UV	VW	WX	XY	YZ
Ground Distance in m	13.3	15	9.5	9	15	6	6.3	6	6	15	14	15.5	8.5	22	37	20.5	21	20	16.5	22	16	43	22	21
Horizontal Distance in m	13.27	14.9	9.49	9	15	5.967	6.265	5.992	5.99	15	13.98	15.49	8.5	21.95	37	20.5	20.961	20	16.5	22	16	42.974	21.997	20.993
Vertical Distance	0.928	1	0.414	0	0.8	0.627	0.659	0.314	0.31	0.5	0.733	0.676	0.5	1.535	1.29	0.89	1.282	0.8	0.58	0.4	0.56	1.501	0.384	0.55
Gradient in % in decimal	0.0225	0.06	0.05	0.06	0.055	0.105	0.105	0.055	0.045	0.055	0.045	0.035	0.055	0.055	0.06	0.07	0.035	0.04	0.06	0.04	0.035	0.035	0.02	0.025
Effective check dam in m	0.45	1	0.7	1	0.8	1.1	1	1.1	0.9	0.8	1.1	1.1	1.2	1	1	1.15	1.1	1.2	1.3	1.3	0.5	1	0.8	0.9
compensation gradient % decimal	0.03	0.00	0.03	.003	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.030	0.03	.03	0.03	0.03	0.03	0.03
Ground Distance in m																								400.1
Total horizontal distance in m																								**399.651**
Total vertical distance in m																								**17.506**
Av. gradient in decimal																								**0.05**
Av. Effective check dam in m																								**1**
Av. compensation gradient in decimal																								**0.03**
Number of check Dam																								19

The spaces between check dams can be determined according to the compensation gradient and the effective height for the check dams. The gradient between the top of the lower check dam and the bottom of the upper one is called "compensation gradient" which is the future or final gradient of the gully channel. Field experience has demonstrated that the compensation gradient of gullies is not more than 3 %.(FAO, 1986), as shown Table 01.

The spacing of check-dams was determined by using an empirical formula (FAO, **1986).**

S = 1.2H/G……… (3)

Where; **S** it the spacing between check dams in meters **H** is the effective height of the check-dam (spillway height in m),**G** is the gully gradient in decimal.

Soil sampling was indispensable to obtain the dry bulk density of the main soils in the area to calculate the sediment yield of the gullies. The dry bulk density (ρd) in g $cm^3$was expressed by the following equation

$\boldsymbol{\rho d = Ms/Vt}$**……………………………………………………………………………………………………... (4)**

Where**ρd**:The dry bulk density in g cm^3**Ms:** is the mass of the dry sample (g) and $\mathbf{V_{t:}}$is the total volume (volume of the wet sample) in cm^3.

Samples were taken in the gully beds by using a cylindrical core sampler with a volume of 100 cm^3. The samples were taken spread out through the area and gullies and only the main occurring soils were sampled. In total 15 samples were taken, randomly at upper, middle and lower part of gully taken. To get the dry weight of the soil samples, the samples were oven dried at 105 degrees Celsius for 24 hours. The results were processed and the outcomes were used to calculate an average dry bulk density of gully. The sediment yield accumulation was determined.

$\boldsymbol{Sy = (V1 - V2)(BD)}$**…………………………………………………………………………………………… (5)**

Where **sy**: sediment yield in tone $\mathbf{V_2}$ is the current volume of the gully in m^3 and $\mathbf{V_1}$istheinitial volume at the start of the study period. BD: average bulk density of soils in the gully bed.

Household's questionnaire survey

After the gully rehabilitation, participated households were selected simple random sampling technique to test their attitude on gully land rehabilitation. The sample size was determined based on the equation recommended for survey studies (FAO, 2012).

$n = \left(\frac{z}{m}\right)^2 P(1-P)$ OR $n` = \frac{n}{1+\frac{n}{N}}$ **…………………………………………………………...** (6)

Where, is number of sample size when population

Z, is 95% confidence limit i.e. 1.96

P, is 0.06 (proportion of the population to be included in the sample

M, is the margin of error

N, is population size

About 760 HHs were participated in gully rehabilitation. Among them 10% of HHs were selected and interviewed to evaluate their perception on gully erosion and its rehabilitation. Accordingly, 76 HHs were selected and conducted to generate information closed and open ended questionnaires. The collected data were systematically coded and analyzed using descriptive statistics by employing Statistical Package for Social Sciences (SPSS) version 20.0 while quantitative data were analyzed by empirical formula. Collected data have been represented with the help of series of tables, figures and frequency distribution.

RESULTS AND DISCUSSION

Farmers' perception causes of soil erosion

Soil erosion as a vulnerability to agricultural production and sustainable agriculture is the most important identified farmers' knowledge on perception soil erosion. As shown Figure 02, 42 % of respondents believed that absence of protection measures that was the most significant cause of soil erosion followed by 23.7% of the farmers who considered that deforestation. In addition, 19.7% revealed that improper farming system was also the most important major causes (Figure 02). This finding showed that there is some gap of extension service to promote and popularize soil and water conservation technologies for land users to protect their land from water erosion to implement mechanical, biological and agronomical conservation measures. Soil erosion by water in Ethiopia, is what has been observed under numerous case studies. For instance, Akliluand Graaff(2006) indicated that Farmers expressed the opinion that the inappropriate land use causes soil erosion by water in Ethiopia's high land areas Beressa watershed in the central highlands of Ethiopia. In Ethiopia, rapid population growth, cultivation on steep slopes, clearing of vegetation and overgrazing are the main factors that accelerate soil erosion (Hurni, 2002).Similar with the above studies, a study by Temesgen et al. (2014) reported that the causes of soil erosion in Dera district, north western Ethiopia were cultivation of steeper slope, intensive cultivation without fallow, lack of soil conservation measures, lack of sense of ownership, deforestation, over grazing, use of crop residues for animal feed and fuel, and heavy rain fall.

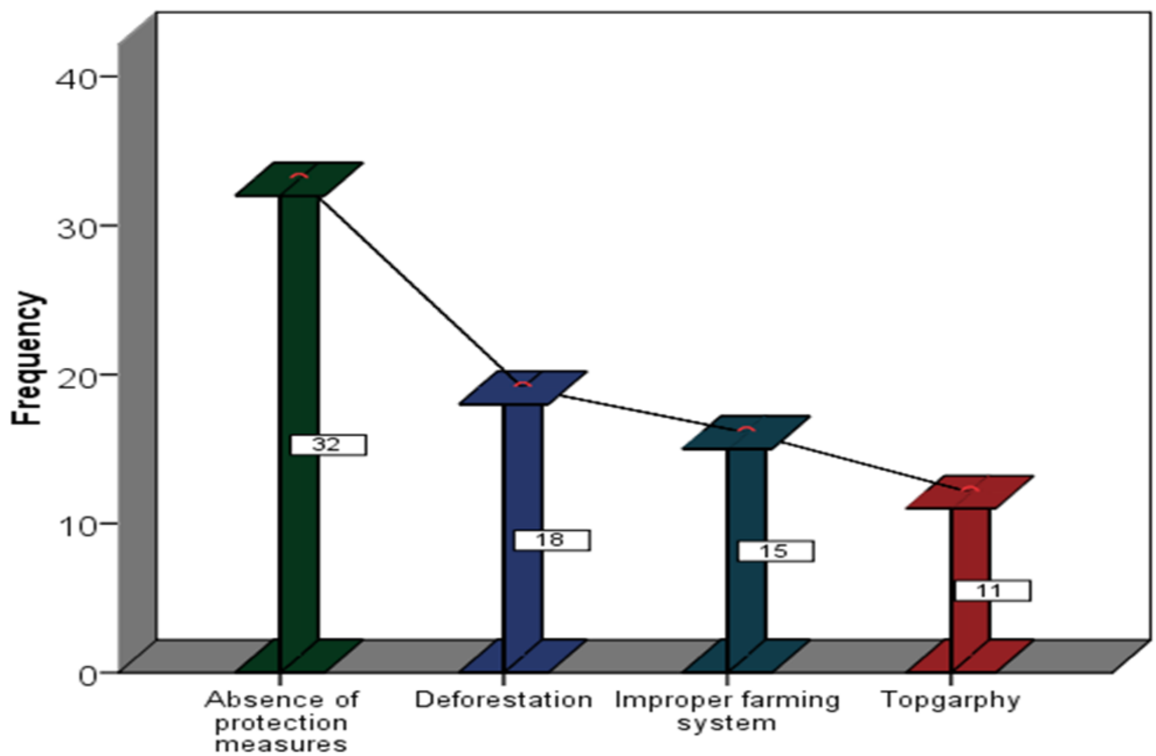

Figure 2: Farmers partition major causes of soil erosion in study area.

Perception and Attitude of Farmers Gully Formation and Consequences

Sampled respondents' perceived that the majority causes of gully formation were improper drainage during road construction (40.8%), inappropriate land use system(36.8%), deforestation (17.1%), trails and foot paths (3.9.%) and overgrazing (1.3%) respectively (Figure 03).

As farmers explained that inappropriate drainage of culverts and ditches and cut the land along to the slope runoff concentration are identified as the major causes of gullies formation. In addition, community interviewed, even if they constructed inappropriate runoff drainage system and land wasted by gully system, the mitigation measures were not under taken or absences awareness of gully rehabilitation program by the community and localized government. The result agrees with previous other authors (Valentin et al., 2005) who discovered that gully expansion due to road construction and building activities in urban environments. Man-made causes were improper land development, construction of road, livestock and vehicle trails and unprotected feeder roads in Alalicha Watershed, Southern Ethiopia (Alemu and Awdenegest,2014), Solomon et al. (2012) studied at central high land of Ethiopia indicated that improper drainage of culverts and ditches and concentration of water along the road are identified as the major proximate causes of physical land degradation through the formation of gullies.

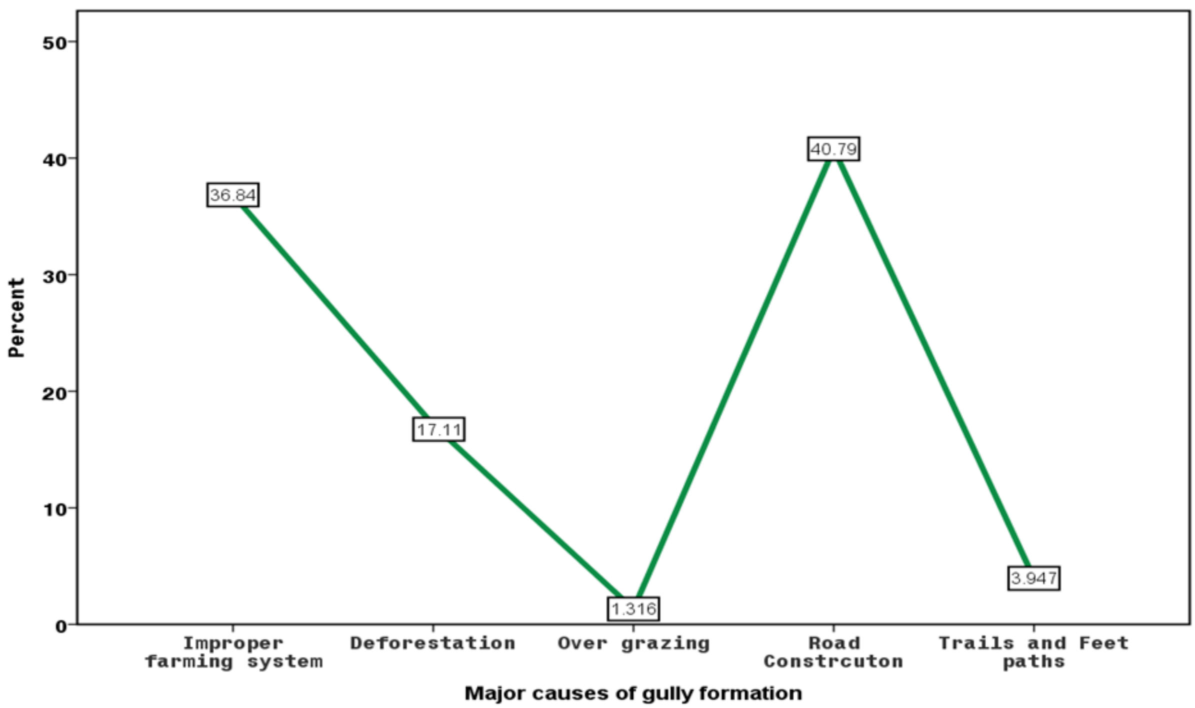

Figure 3: Farmers' perception major causes gully formation in study area

As can be seen from Table 02, only about 1.3% of farmers perceived that there is no gully erosion problem on their farm land. The remaining 98.7% of farmers perceived that there is gully erosion problem on their farm land.

About one-third of farmers interviewed (19.7%) rated the problem to be gullied low on their cultivation land, one-sixth of interviewees (about 17.1%) indicated that there is severe level of gully erosion and the remaining 63.2% indicated that there is moderate gully erosion problem. Therefore, severity of gully problem in their farm land was almost categorized under moderate.

In the study area the perception of farmers about the impact of gully on farm production were different among respondents. About third-fifth of farmers interviewed (61.8%) perceived that there is moderate dynamics gully erosion problem on their farmland. About one-third of farmers interviewed (28.9 %) rated the problem to be severe on their cultivation land. one-tenth of interviewees (about 9.2%) indicated that there is low level of erosion Table 2.

About 89.5 % of locals farmers perceived that negative consequences of gully formation in their farms while, few respondents didn't understand gully formation in their farm. Sampled respondents confirmed that 50.0, 39.5, 6.6 and 3.9 % the consequences of gully formation were loss of land productivity, destruction of farm land, damage to infrastructure and lowering of the water table, respectively, Table2.This result is similar with the findings of Nyssen et al. (2004)studies at Ethiopian highlands indicated that the development of gullies has led to an enlarged drainage, resulting in soil moisture decrease and a corresponding crop yield reductionin central high land.

Table: 2: Farmers' perceptions of gully erosion vulnerabilities in the study area.

Perception on gully erosion	Respondents (%)
Farmers' perception of gully erosion	
Yes	98.7
No	1.3
Severity gully problem	
Low	19.7
Moderate	63.2
Severe	17.1
Impact of gully on farm production	
Severe	28.9
Moderate	61.9
Low	27.8
Negative consequence of gully erosion on farm land	
Yes	89.5
No	10.5
consequences of gully formation	
Loss of land productivity	50.0
Damage to infrastructure	6.6
Lowering of the water table	3.9
Destruction of farm land	39.5

Farmers' perception towards gullied land rehabilitation and integration works with stallholders

The households interviewed presented in Table 3 explained that before Pawe Agricultural research Center (PARC) collaboration with community more than half of respondent (53%) were not understood gully rehabilitation in their farm land while remaining were understood. On the other hand, create awareness gully formation and consequences, mobilization of community and disseminated information were contributed to initiation of gully rehabilitation leads to Agricultural and Rural Development Office followed to PARC 55.3 % and 34.2 % respectively. Interestingly, only 59.2 % found that continuously an extension service was effort that initiated the community to participate gully rehabilitation Table 04. In future, if the gully appeared in their farm land, the respondent perceived that 40.8, 30.3, 25.0 and 3.9% will be taken responsibilities for control the gully land owner, Community, Agricultural development office and PARC, respectively. This finding indicated that research science based development with integration multi-institutional is the best bet approach community based participatory gully rehabilitation in study area. Similar approach was reported by Water and Land Resource Centre [WLRC], (2015) active participation and collaboration of land users, local community organizations, extensionists, researchers and policy makers at all stages of gully development processes.

The study findings showed that among the sampled respondents confirmed that were attitude on gully control and development program in future highly acceptable followed by modern acceptable 84.2% and acceptable 14.5%, respectively whereas interestingly, only 1.3% respondents was acceptable for gully rehabilitation. Similar approach was reported by (WLRC, 2015) communicating bylaws for controlling free grazing and equitable share of benefits are important incentives to sustain the uptake and scaling up of the gully rehabilitation.

Table 3: Local people perception of gully control, initiation, responsibility and acceptance of gully rehabilitation in the study area.

Variables related to gully rehabilitation	Modalities	Positive responses	
		Number	%
gully erosion control before facilitation of pawe research center	Yes	35	46.1
	No	41	53.9
Initiation of Institutions to control gully erosion in your area	Agricultural Development Office	42	55.3
	NGOs	7	9.2
	Pawe Research Center	26	34.2
	By myself	1	1.3
The derived effort that initiated that participate gully rehabilitation	Payment	3	3.9
	Extension services	45	59.2
	Land degradation	23	30.3
	Enforcement	5	6.6
Responsibilities bodies that will be taken to control the gully	Land owner	31	40.8
	Agricultural development office	23	30.3
	Pawe Agricultural research Center	3	3.9
	Community	19	25.0
Farmers' attitude on gully control development program in future	Highly acceptable	64	84.2
	Modern acceptable	11	14.5
	Acceptable	1	1.3

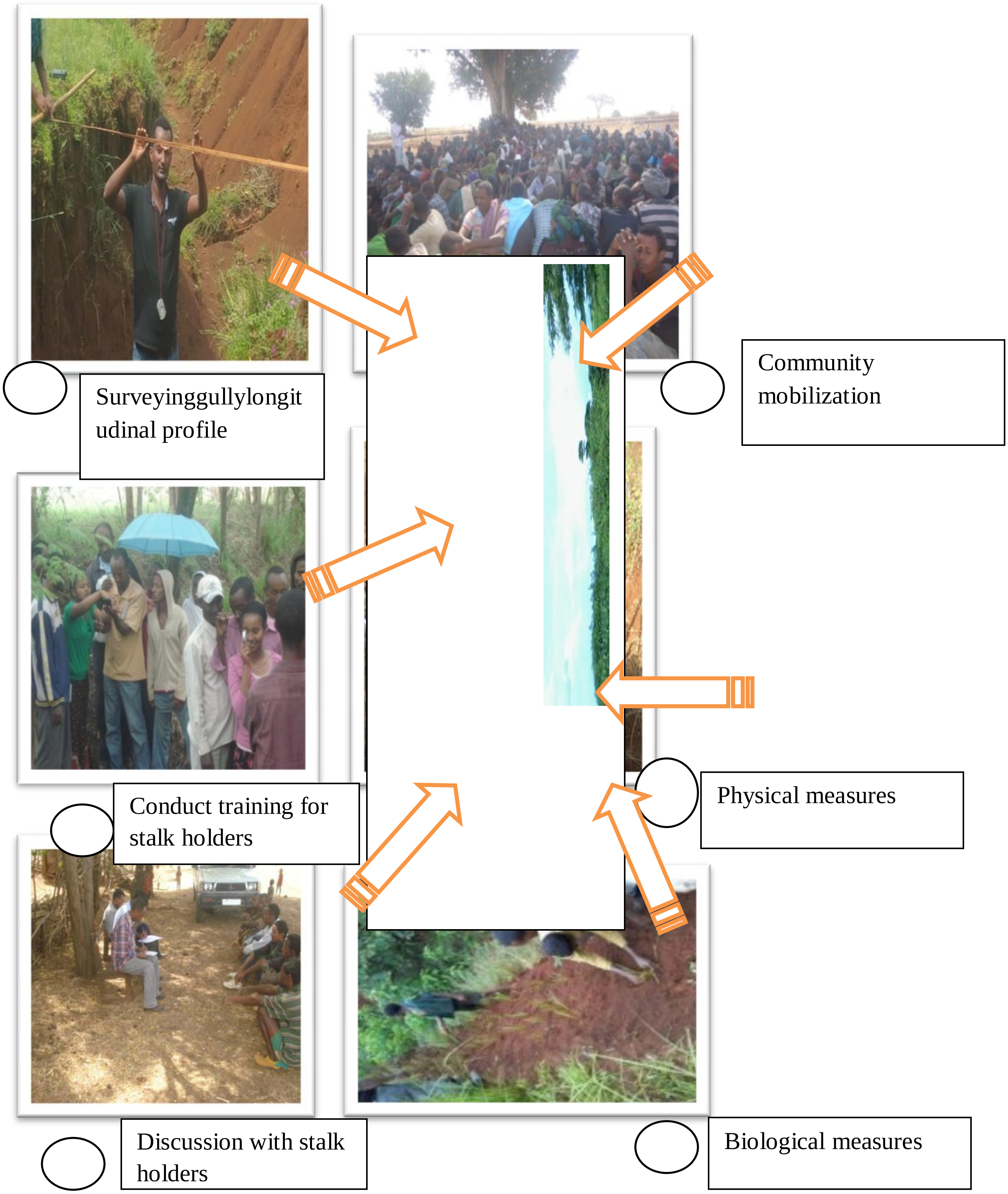

Figure 4: Diagrammatically illustrate steps of gully rehabilitation process in study area

Impact of gully rehabilitation on longitudinal gully profile

Double brushwood posts check dams were constructed based on recommended specification with together community actively participation to rehabilitate the gully starting from 2010 up to 2013 because of the availability of brush wood materials in the study area. Criteria agrees with previous works FAO (1986)gully control measures are based on the size of the gully catchment area, the gradient and the length of the gully channel and arability of martials. Gully control in Northern Ethiopia is mainly done through loose rock and gabion check dams, but not absence of stones and/or negative impact gabion check dam technique costly comparable with others can best be used in critical positions(Nyssen et.al.,2007).The vegetative materials were used Vetiver grass for stabilized gully walls and low land bamboos were used for preventing for gully wall stabilizing. In gully rehabilitation the Vetiver grass barriers and very good stabilizer (Hurni et al., 2016)

The rule is used in the field to decide if a gully is active or not and continue and discontinue gully rehabilitation so that it fulfilled the criteria. According to the rule mentioned by Oostwoud et al. (2000) a gully is active if at least one of the following is observed undercut or plunge pool causing cave-in, a vertical or nearly vertical wall, no vegetation on the gully wall, tension cracks and Side wall collapse and sediment on the gully floor.

Gully Slope: starting from down to upland the gully channel was measured by clinometers to determine the gully gradient. Before intervene (2010) its average gradient was 5% or 2.9^0 whereas later than (2013) it reduced to 4% or 2.3^0due to integration of mechanical double wood posts check dams with biological stabilizing of gully bed channel, gully slide side bank and stopping scouring gully heads and reduces the speed of concentrated run-off and deposited sediment in face to check dams as shown Fig 3.The result agrees with works Nyssen *et a*l. (2007), discovered reduce the slope gradients by breaking the gully section into shorter slope lengths, retain sediments.

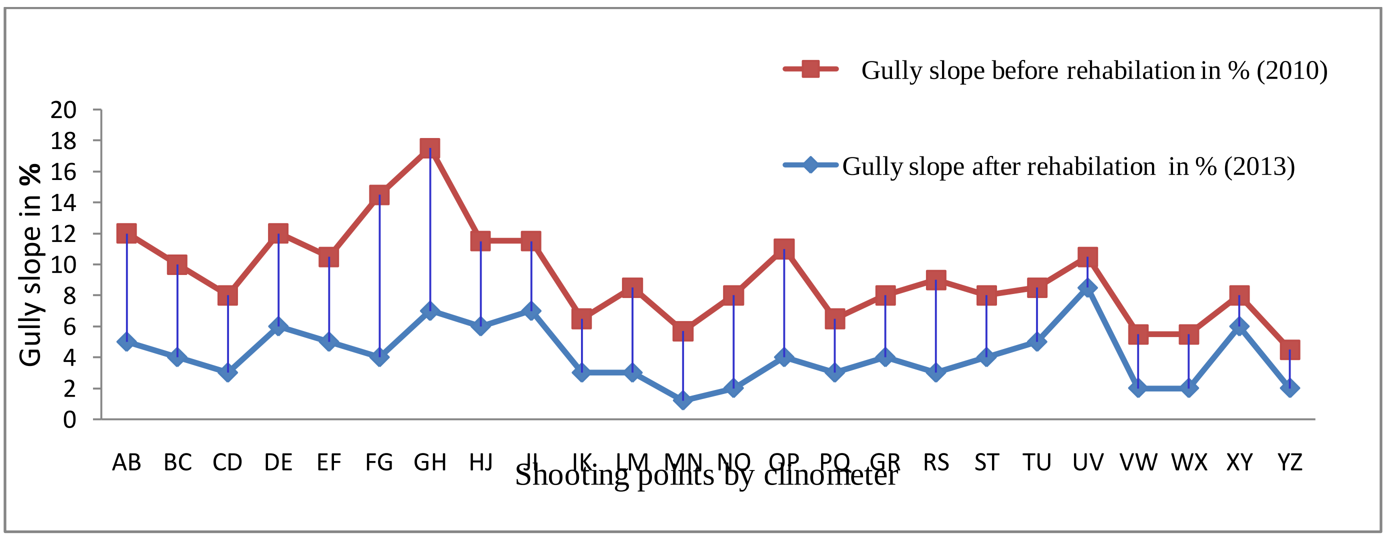

Figure 5: Gully gradient difference before and after rehabilitation

Gully Vertical interval and cumulative: Before gullied land treated gully bed channel and vertical interval was measured, the commutative gully vertical interval was calculated by applying trigonometric law equation$\mathrm{VI} = \sin\theta * \mathrm{GD}$

Where, **VI** is vertical interval gully segment in meters, **sinθ**, is an angle between horizontal interval and ground distance of the gully segments and **GD:** ground distance of the gully segments.

The former mean each shooting points VI was 0.729m while after treated the gully VI reduced in to 0.623m in 2013. The result showed that gully longitudinal channel decrease the gradient slow flow run-off that leads sediment materials deposited and encouraging regenerating vegetative resources at end sodding gully channel. The same to, cumulative vertical distance of gully in 2010 was 17.50m but after intervention its vertical distance reduced to 14.94m in 2013 as shown **Figure 4.**

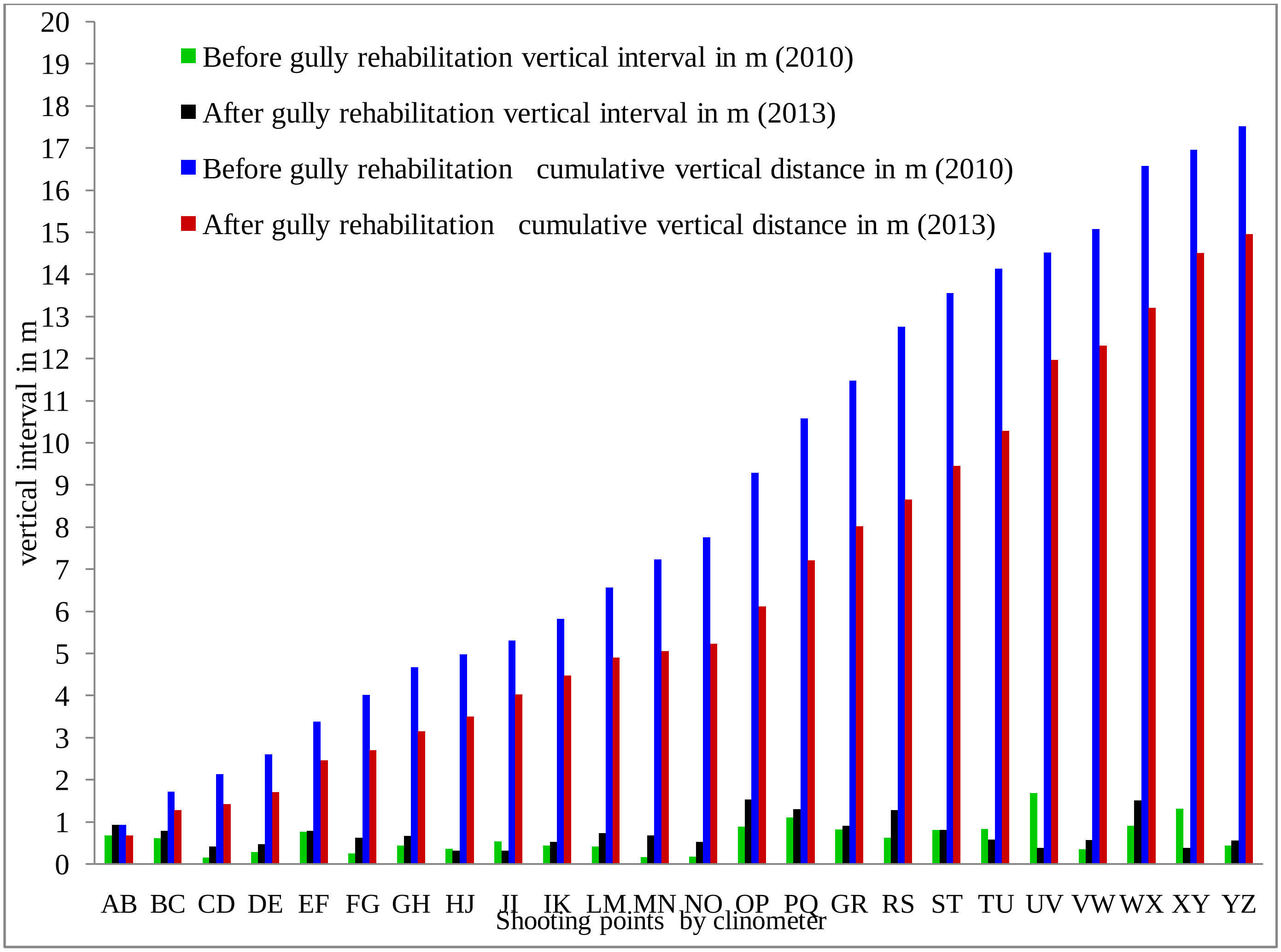

Figure 6: Gully rehabilitation on impact gully vertical interval and cumulative vertical distance

Gully Depth: before intervention the average gully depth was 1.94m. After treated its depth decreased into 1.27m. Within three years in average 0.69m gully depth coming up and filled by deposition of eroded materials that the removal of soil or soft rock material by water upper catchment as shown Fig.5. This agrees with results of Kirubel*et al.* (2011) who reported that after 17 years Check-dam-accumulated soil ranges 0.4-1.5 m depth and more than 1.5-m soil was deposited in the gullies with check dams integrated with biological measures at Medego watershed in Tigray, northern Ethiopia.

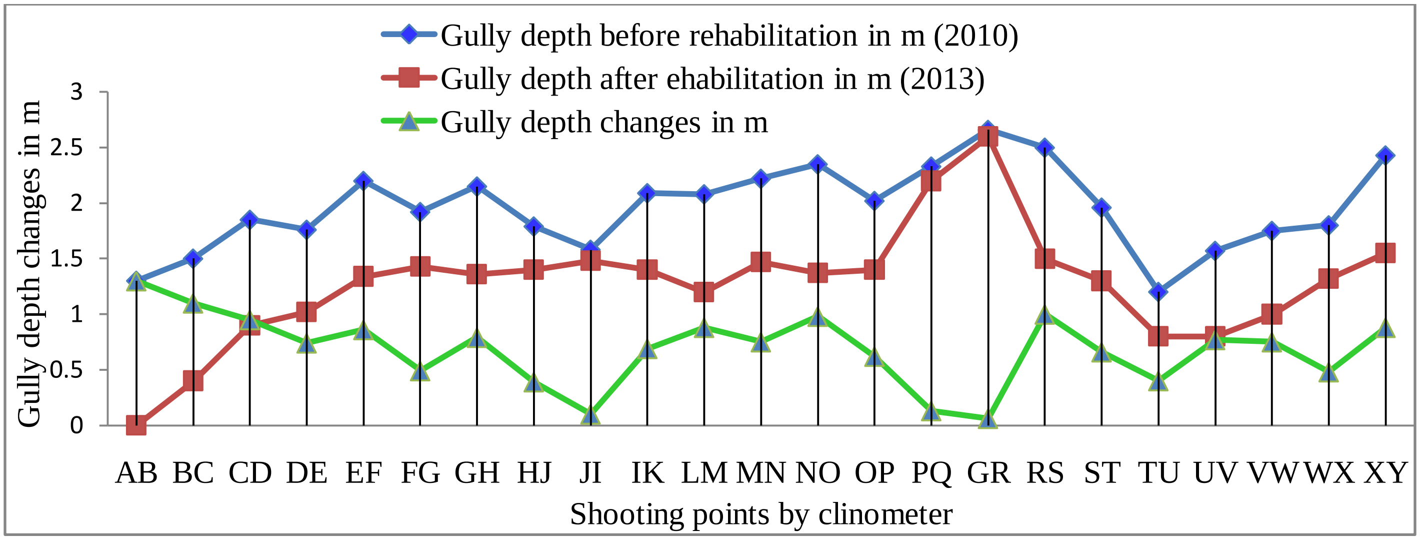

Figure 7: Before and after rehabilitation gully depth changes

Figure 8: Shows the deference between before and after gully rehabilitation the same site

Gully top and bottom width

Before treated (2010), the average gully top and bottom width were 5.92m and 2.27m, respectively, while after rehabilitation (2013), its average top and bottom width became 6.11m and 1.46m, respectively. These measurements indicate that gulling top width increased because vertical gully wall were converted into gentle slope in order to convenient for planting vetiver grassto stabilized gully wall.

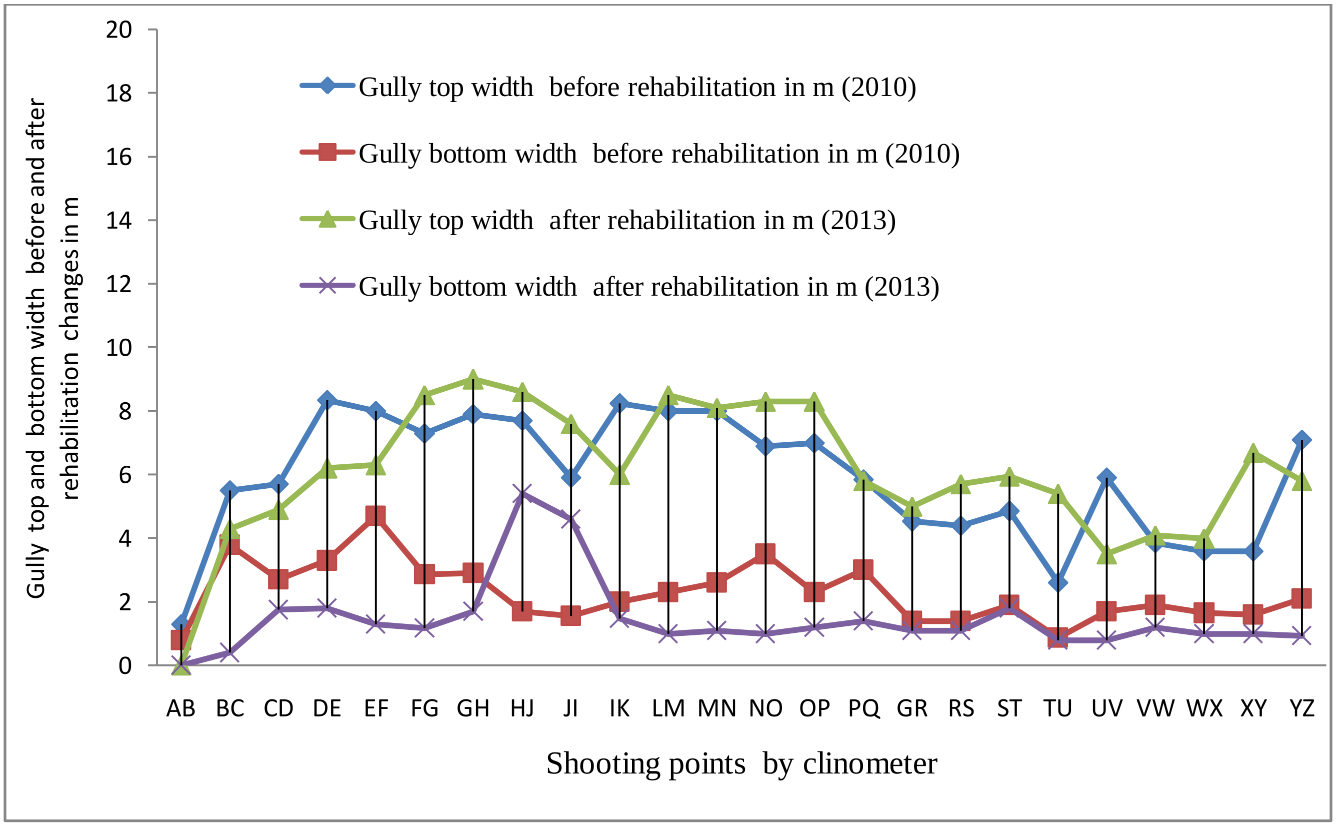

Figure 9: The relative positions, widths (top and bottom) and depths of gully segments compared before and after rehabilitation (2010 - 2013).

Gully volume: The eroded volume gully was calculated using the cross sectional area and its longitudinal length. Thus, before intervention the volume gully was 2,995.41.38m^3 where as in 2013 gully accumulated sediment yield 1,515.5 m^3 soils the volume of gully reduced in to 1479m^3 as Figure 8.

Cylindrical core sampler was used to take undisturbed soil samples from upper, medium and lower parts of the gully bed to determine soil bulk density. Fifteen samples were collected and mean bulk density was taken from the gully bed channel and 1.22 g/cm^3. Finally, Gully the sediment yield was accumulated 1,849,032 kg/ 1849.032 tones soil. Similar result was found five learning watersheds in Amhara Region, Ethiopia (WLRC,2015) concluded that gully rehabilitation, at off-site, there are benefits in terms of increased stream flows during the dry season and recharging of aquifers, reduced damage on roads and houses, and reduced Downstream reservoir siltation.

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Figure10: shows the deference between before and after gully rehabilitation the same site and season.

CONCLUSION AND RECOMMENDATIONS

Gully erosion is the worst form of erosion and land cancer so that as principle prevention is better than Cure. The results obtained from HHs interviewed that the major causes of gully formation were improper drainage during road construction (40.8%), inappropriate farming and land use system (36.8%), deforestation (17.1%), trails and foot paths (3.9. %) and overgrazing (1.3%), respectively. Before gully rehabilitation (2010) necessary gully profile dimension measurements (slope, depth, top and bottom width, vertical interval and commutative) were in average 5%, 1.86m, 5.80m, 2.23m, 0.729m and17.50m, respectively. After treated (2013) its profile (slope, depth, top and bottom width, vertical interval and commutative) were reduced into 4%, 1.47m, 5.93m, 1.41m, 0.623m and 14.94m respectively. In 2010 the total volume of gully was 2995.5m3 while after rehabilitated (2013) it was reduced into 1,479.9m^3 which was accumulated 1,515.6m3 or 1849.032 tones soil with three years. Thus, gully rehabilitation, at off-site, there are benefits in terms of increased stream flows during the dry season and recharging of aquifers, reduced damage on roads and houses, and reduced downstream reservoir siltation.

Poor gully maintenance, improper of spillway, apron and Improper spacing of check-dams and lack of integration check-dam with biological measures and lack of keying the check-dam to the floor and sidewalls of the gully were also be technical gaps. Brush wood check dam is suitable for small catchments.

In general, the brush wood should have branches, flexible, long, straight and breakable. The tree branches are laid between the two rows of posts across the gully, and thoroughly packed. There is a risk of the brushwood being removed by flowing water. Therefore, it is necessary to fix the brushwood with rope or wire. When doing so, two or more persons should stand on the brush to press it down. Upstream of the wooden check-dam, sods can be laid and packed to prevent direct flow into the apron brush. The vegetative materials vetiver grass, bamboo and Acacia species are vital for gully wall and floor rehabilitation and used as apron. These vegetative materials are taken as input for gully rehabilitation local available, durable and cost effective materials.

REFERENCES

6th International Symposium on Gully Erosion in a Changing World (ISGE).(2013).6th International Symposium on Gully Erosion 06-12 May 2013, Iasi, Romania

Aklilu A.Jan DG (2006). Farmers' views of soil erosion problems and their conservation knowledge at Beressa watershed, central highlands of Ethiopia. *J. of Agriculture and Human Values.*23:99-108.

Alemu, O, AwdenegestM (2014). Extent of Gully Erosion and Farmer's Perception of Soil Erosion in Alalicha Watershed, Southern Ethiopia. *J. of Environment and Earth Science*. 4:74-81.

AmauryF, Jean P, Mitiku ,Jozef D, Jan N(2013).Quantifying long-term changes in gully networks and volumes in dry land. Environments: The case of Northern Ethiopia. Journal homepage: www.elsevier.com/locate/geomorph,Geomorphology 201 (2013) 254-263.

Ayele,GK, Azalu AG, Meseret BA, Seifu AT, Daregot BT, EddyJL, TammoSS, CharlesFN(2015). The economic cost of upland and gully erosion on subsistence agriculture for a watershed in the Ethiopian highlands. *African J. of Agricultural and Resource Economics.* 10: 265-278.

BelaynehL, Bantider,A,Moges A (2014).Road construction and gully development in Hadero-Durgi road project, Southern Ethiopia. *Ethiopian J. of Environmental Studiesand Management*, 7supp.720-730. *doi: http://dx.doi.org/10.4314/ejesm.v7i1.3S*

BewketW, SterkG 2002. Farmers' participation in soil and water conservation activities in the Chemoga Watershed, Blue Nile basin, Ethiopia. Land Degradation& Development, 13(3), 189-273.

Billi,P.,& Dramis, F. (2002) Geomorphological investigation on gully erosion in the rift valley and the northern highlands of Ethiopia, Catena, 50, 353-368.

Engda, M. (2000). Agro-climatic classification of Ethiopia.

Engda, M. (2000). Agro-climatic classification of Ethiopia.

Engda, M. (2000). Agro-climatic classification of Ethiopia.

EngdaM.(2000). Agro-climatic classification of Ethiopia. *Ethiopia. J. of Natural Resources.* 2:115-135.

Ethiop. J. Nat. Resour. 2(2): 115-135.

Ethiop. J. Nat. Resour. 2(2): 115-135.

Ethiop. J. Nat. Resour. 2(2): 115-135.

FAO (1986). Watershed management field manual Gully control. FAO Conservation Guide 13/2. Rome.*http://www.fao.org/docrep/006/ad082e/ad082e00.htm*

FAO2012. Phenotypic characterization of animal genetic resources. FAO Animal Production and Health Guidelines No. 11.*http://www.fao.org/docrep/015/i2686e/i2686e00.htm*

FranklA, PoesenJ, De DapperM, DeckersJ, HaileMitikuNyssen J2012. Gully head retreat rates in the semiarid Highlands of North Ethiopia. Geomorphology. 173:185-195.

Hurni H (1986). Guidelines for development agents on soil conservation in Ethiopia. Soil Conservation Research Project. Community Forests and Soil Conservation Development Department, Ministry of Agriculture Addis Ababa Ethiopia.

Hurni H (2002). Current international actions for furthering the sustainability use of soils. Symposium paper no.63 on 17th WCSS, 14-21 August 2002. 1-8 pp.Special Paper 252: 139-155.

HurniH, Berhe WA, Chadhokar P, Daniel D, GeteZ, Grunder M, KassayeG (2016). Soil and Water Conservation in Ethiopia: Guidelines for Development Agents. Second revised edition. Bern, Switzerland: Centre for Development and Environment (CDE), University of Bern, with Bern OpenPublishing (BOP). 134 pp.

KirubelM, Gebreyesus BT(2011). Impact assessment of soil and water conservation measures at Medego watershed in Tigray, northern Ethiopia. Maejo Int. J. Sci. Technol. 5(03): 312-330.

[MitikuH, Herweg K, Stillhardt B (2006). *Sustainable Land Management -A New Approach to Soil and Water Conservation in Ethiopia.* Mekelle, Ethiopia: Land Resources Management and Environmental Protection

Department, Mekelle University; Bern, Switzerland: Centre for Development and Environment (CDE), University of Bern, and Swiss National Centre of Competence in Research (NCCR) North-South. 269 pp.

Moges A, Holden NM (2008). Estimating the rate and consequences of gully development, a case study of Umbulo catchment in southern Ethiopia. Land Degradationand Developmentn19(5): 574-586.

Nyssen J (2001). Erosion processes and soil conservation in a tropical mountain catchment under threat of anthropogenic desertification - a case study from Northern Ethiopia. Ph.D. thesis, KULeuven, Belgium, 380 p.

NyssenJ (1995). Soil erosion in the Tigray Highlands (Ethiopia): Natural and human environment in its relationship to soil erosion. Geo-Eco-Trop. 19:51– 82.

NyssenJ, Descheemaeker K, Nigussie H, Mitiku H, DeckersJ, Poesen J. (eds.), 2007. Lessons learnt from 10 years research on soil erosion and soil and water conservation in Tigray. Tigray Livelihood Papers No. 7, Mekelle: Zala-Daget Project, Mekelle University, K.U.Leuven, and Relief Society of Tigray, Africamuseum and Tigray. Bureau of Agriculture and Rural Development, 53 p. ISBN 978-90-8826-027-8.

NyssenJ, Poesen, J, Moeyersons J, DeckersJ, Mitiku H. Lang A (2004a). Human impact on the environment in the Ethiopian and Eritrean highlands state of the art. Earth-Science Reviews 64 (2004) 273-320.

Nyssen J, Poesen J, Moeyersons J, Luyten C, Veyerety Picot M, Deckers J, Mitiku H, Govers G (2002). Impact of road building on gully erosion risk: a case study from the northern Ethiopia highlands. *Earth Surface Processes and Landforms.* 27: 1267-1283.

Nyssen J, VeyretPicotM, Poesen J, Moeyersons J, Mitiku H, DeckersJ, Govers G(2004a). The effectiveness of loose rock check dams for gully control in Tigray, northern Ethiopia. Soil Use and Management 20 (1):55–64.

Obsa ADerejeATesfahun M (2017).Evaluation of brush wood with stone check dam on gully rehabilitation at Assosa, Benishangul gumuz, Ethiopia.*International Journal of Agricultural Research and Review*. 5(9): 663-669.

Oostwoud, DJ, Poesen J, Vandekerckhove L, Ghesquiere M (2000). Spatial distribution of gully head activity and sediment supply along an ephemeral channel in a Mediterranean environment. Catena 39:147–167.

Poesen J, DeckersJ, Mitiku H, NyssenJ, Bruneel S (Eds.), 2006. HighLand2006 Symposium on environmental change, geomorphic processes, land degradation and rehabilitation in tropical and subtropical highlands. Mekelle, Ethiopia, September 19-25, 2006. Mekelle University, K.U. Leuven, VLIR, Africamuseum, UNESCO, Book of abstracts, p. 104.

PoessenJ, Nachtergaele J, VerstraetenG, ValentinC (2003). Gully erosion and environmental change: importance and research needs. Catena. 50(2): 91133.

Solomon A, Mekuria A. HameedS (2012). Localised Environmental Degradation Due to the Offshoots of Highway Development Projects: The Case of Central Ethiopian High Lands. Global Advanced Research Journals. 1(5) : 088-098.

Tebebu TY. (2009). Assessment of hydrological controls on gully formation near Lake Tana, northern highlands of Ethiopia (Master of Science thesis). Cornell University.

Tebebu TY, Abiy AZ, Zegeye AD, Dahlke HE, Easton ZM, Tiluhan SA, CollickAS, KidnauS ,Moges S, Dadgari F. Steenhuis TS (2010). Surface and subsurface flow effect on permanent gully formation and upland erosion near Lake Tana in the northern highlands of Ethiopia. *Hydrology and Earth System Sciences* 14(11):2207–2217.

Tebebu TY, ZegeyeA.D., Langendoen EJ, Ayele GK, Tilahun SA, AyanaE.K ,Steenhuis TS. Arresting gully formation in the Ethiopian highlands. In:WoldeMekuria. (ed). 2013. Rainwater management for resilient livelihoods in Ethiopia: Proceedings of the Nile Basin Development Challenge science meeting, Addis Ababa, 9–10July 2013. NBDC Technical Report 5. Nairobi, Kenya: International Livestock Research Institute.

Temesgen G, Amare B. Abraham M (2014). Farming households' knowledge and perception on soil degradation in Dera Woreda, Ethiopia. *Agricultural Science, Engineering and Technology Research.*2(3): 1-103.

Tilahun SA, Guzman CD, Zegeye AD, Ayana EK, Collick AS, Yitaferu B, SteenhuisT (2013). Spatial and temporal patterns of soil erosion in the semi-humid Ethiopian highlands: a case study of Debre Mawi Watershed. In, Nile River Basin: ecohydrological challenges, climate change and hydro politics. Melesse AM, Abtew W, Setegn SG (eds). Springer Science Publisher: Switzerland. P 149-163.

Valentin C, Poesen J,and Yong Li (2005). Gully erosion: Impacts, factors and control. Science directs 63: 132-153.

Valentin, C, PoesenJ , Li Y (2005) .Gully Erosion: A Global Issue. Proc. Second International Symposium on Gully Erosion, Chengdu, China, May 2002. Catena 63 (2–3): 129–330.

Waterand Land Resource Centre(2015). Gully Rehabilitation. What Does It Costs to Heal Gullies and Make them Productive? Brief No. 3

Waterand Land Resource Centre 2015. Learning Watershed. An Approach for Participatory Integrated Water and Land Resources Management and Livelihood. Brief No. 1