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Research Article

Participatory Demonstration of Gully Treatment Method for Gully Rehabilitation in Dollo Schem, Kamba District, South Ethiopia

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Abstract

Gully erosion is the major environmental problem threating huge area of agricultural lands in south Ethiopia, particularly. The present study aimed at evaluating demonstrates gully treatment methods for gully rehabilitation in Kamba, South Ethiopia. On farm filed experiments, key informant interview and focus group discussion were used to collect and analyze experimental data. The result of this study indicates that integration of check dame with Elephant grass have significant effect on gully rehabilitation. This integration was reduced gully depth, slope gradient, gully volume and soil loss. Slope of gully bed was reduced by 60%, 46% 37% respective years. Similarly gully depth reduced by 2.54m, 1.72m and 1.456m while gully volume was reduced by 37.44m3, 8.81m3 and 4.32m3 due to check dam as the same order of slope changes. Data such as sediment deposition and biomass production were collected, to investigate their effectiveness in reducing soil erosion and biomass production. Over a period of two years practices caused measurable gully morphology resulted soil calculated was 248.41kg of soil were deposited in 12.76m2 area. According to Focus group discussion farmers viewed these gully rehabilitation measures was positively, apart from the high labour, input materials and technical requirements of stone check dam. Based on the results the study concluded that check dam integrated with Elephant grass in the gully bed have positive effective rehabilitate gully erosion in the study area. Therefore, farmers should use gully rehabilitation techniques to preserve their land.

Keywords: Participatory; Grass biomass; Gully rehabilitation.

BACKGROUND

Land degradation due to soil erosion which is caused by the hydrodynamics of geo-environmental problems in countries of semi-humid and semi-arid Mediterranean [1,2], as it contributes to a significant soil loss, it is a major concern in these countries [3]. For example, gully erosion contributed up to 70% of soil loss in each of the Loess Plateau of China [4]. Although gully erosion is a global problem and occurs in all geographical areas, Africa is the worst-hit continent [5]. Around 20 to 25% of the land area of Sub-Saharan Africa (SSA) is severely affected by gully erosion [6].

In Northern Ethiopia, land degradation due to gully was sever [7], about 50% to 80% of the overall sediment production was contributed by gully erosion [8], which is also specifically ranged from 28% in semi-arid Tigray [9], and to 90% in sub-humid highlands of Amhara [3]. This leads to 100 to 1350 tons/acre annual soil loss from watersheds with valley bottom gullies [3]. In southern Ethiopia, measurements of soil erosion within gullies ranged from 11 to 30 t ha^{-1} yr^{-1} [10].

The economic costs of soil loss due to gully erosion are high in Kenya; this was estimated to be equal to total agricultural exports [11]. These costs are experienced mostly by rural communities, particularly poorer households, who generate much of their income from the land [12]. Severe gully erosion affects the livelihoods of rural communities in several ways, including the degradation of croplands, land fragmentation [2], reduced livestock carrying capacity of rangelands [13,14], limitation of movement and death both humans and livestock, and increased siltation of freshwater ecosystems and destruction of water infrastructure [15]. Severity of gully erosion is a major cause of increased sediment loads in rivers, but gully rehabilitation has proven to be challenging, with limited success where low-cost gully rehabilitation has been effective with community participation [16].

Across the different countries of the world, there is several development initiatives aimed at controlling gully erosion. However, one of the prevalent challenges in controlling gully erosion is that once the soil has degraded and gullies have formed, complex measures are required to stop their expansion. The rehabilitation of big gullies usually takes several decades and requires huge financial resources [17,18]. Available technologies need to be contextualized to a specific site to be effective, considering costs, labour and available resources in addition to the physical challenge [19].

The study conducted by Rabinovich [20], better knowledge and understanding can increase farmers' intention to adopt measures to prevent soil erosion. The importance of rehabilitating gullies should be advocated to soil conservation experts, development organizations, and policymakers. This form of environmental protection is often neglected. However, it can provide economic benefit to communities, decrease sediment concentration in rivers, and slow down siltation of downstream reservoirs

To counter this, a number of field experiments in Ethiopia have explored whether low-cost interventions, accessible to individuals or small groups of farmers on their own land, are effective in preventing and rehabilitating gullies at an early stage of their development. Barvels and Fensholt [21], suggested that vegetative measures are effective rehabilitating gullies in the highlands of Ethiopia. A link between farmers' perceptions and their willingness to adopt effective gully erosion mitigation strategies will draw together socioeconomic drivers with biophysical evidence. To reverse land degradation problem particularly gully expansion, it is better to demonstrate gully rehabilitation measures for land scape sustainability. Therefore, the current study was aimed, to

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demonstrate the effective gully treatment method for gully rehabilitation and assess farmer's perception on gully rehabilitation method in Dollo schem, kamba Woreda, Gamo Zone South Ethiopia.

MATERIALS AND METHODS

Study Area Description

The study was conducted in Dollo Schem, Kamba District, Gamo Zone, South Ethiopia Regional State, of Ethiopia. Geographically, it's located between 11^0 27ˊ 0ˊ and $11^0$23'0"N latitude and $03^0$60'15"and $36^0$26'0"E longitude with an altitude range 1115-1219 meter above sea level [Figure 1]. The minimum and maximum annual rainfall of the study area is between 900mm-1500 mm respectively. It has unimodal rainfall distribution pattern, with mean minimum and maximum annually temperature ranging from 28^0c to 38^0c, respectively. 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%.

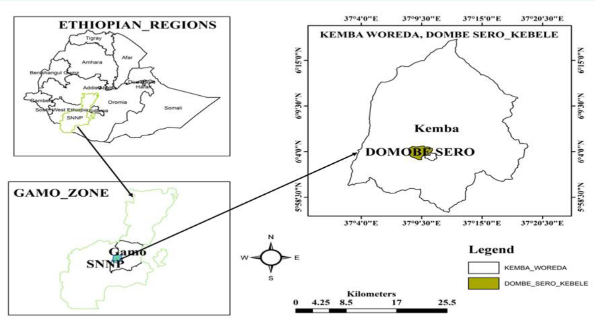


Figure 1 : Location map of the study area

Study Design

This demonstrative research was conducted in Dollo scheme small gully which highly affects the irrigation scheme within the watershed and IFAD project target area. Prior to demonstration, discussion with Farmer's Research Extension Groups (FREG) members was carried out on the severity and impact of gully erosion in the area. After discussion, one long active gully was selected which have similar dimension with less than 3m depth and width near the head with FREG to evaluate and demonstrate the gully head treatment methods on gullies rehabilitation to reduce upward expansion of gully head and associated soil loss. In this gully rehabilitation measures farmers were participated with their own capacity and limited external support. Treatments were set constructing stone check dam with planting Elephant grasses at gully and gully bank. Then, the study compared the treated gully with the baseline data.

Implementation of Gully Rehabilitation Measures

Reshaping is one of gully rehabilitation methods done to stabilize and restore gullies to a desired shape. However, gully was properly reshaped to reduce runoff velocity and to stabilize and restore gullies to a desired shape (evenly sloped area). The height of check dam was minimum 1m and maximum 2m excluding foundation. FREG and trail farmers were encouraged to collect stone, wood and planting materials from elsewhere and participated on design, construction, planting grasses around the gully head and gully banks to stabilize the structure.

Method of Data Collection Type and Source

Based on the demonstrated technologies in the areas, farmers' perception data on gully rehabilitation methods was collected by active participation of FREG. Quantitative data were collected through filed measurement of gully morphology before and after rehabilitation (after rain season) and sediment deposited materials were also determined. Qualitative data were collected though FGD and key informant interviews. Focus Group Discussions (FGD) and field observations were conducted for socio-economic data collections. The group discussant was encompassed different social groups, including model farmers, medium, and lower-class farmers, youth, elders, and female farmers, with in two groups, in each group twelve members totally (twenty-four members) were participated to assess cost and benefit of gully rehabilitation measures.

Key informant interviews were carried out with knowledgeable and influential people at kebele level, such as kebele administrators, Seftnet project focal persons, kebele managers, and development agents, to understand the system and assess the drivers, pressure, extent, impact, response of gully erosion, formation and intervention measures. Secondary data were collected at district and kebele levels from agriculture and project offices (Plate 1).

Plate 1: Photo taken while measuring vertical and horizontal intervals

Before rehabilitation, the gullied volume, top and bottom width, slope, vertical and horizontal distance, ground length and depth parameters were taken by measuring from the gullied cross-section field measurement and survey was carried out in 2022. These measurements were averaged to get an estimation of the volume using the following equation:

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

Where V, is 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 number of check dams was determined by measuring the average gully channel gradient, horizontal and vertical distance. The number of check dams for each portion of the main gully channel was calculated.

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.

The spaces between check dams were determined according to the compensation gradient and the effective height for the check dams. The spacing of check-dams was determined by using an empirical formula (FAO, 1986).

(S) = Height (m)*1.2 .... (3)

Gradient (in decimal)

Where; **S,** is 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.

$$\rho d = Ms/Vt \quad \ldots (4)$$

Where: **ρd,** the dry bulk density in g/cm3: **Ms,** is the mass of the dry sample (g) and: **Vt,** is the total volume (volume of the wet sample) in cm^3.

Samples were collected from the gully beds by using a cylindrical core sampler with a volume of 100 cm^3. The samples were collected spread out through the area and gullies and only the main occurring soils were sampled. A total of 5 samples were collected, randomly at upper, middle and lower part of gully. To get the dry weight soil sample were oven dried at 105c^0 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 by the following formula.

$$Sy = V1 - V2\ (BD) \quad \ldots (5)$$

Where: **sy,** is sediment yield in tone: **V2,** is the current volume of the gully in cm^3, **V1,** is the initial volume at the start of the study period and: BD, average bulk density of soils.

The amount of sediment deposited behind each check-dam was determined by inserted gauged erosion pins at the center of check dam. A cylindrical core sampler was used to collect undisturbed soil samples at each gully to determine the bulk density of the soil. Moreover, gully cross sections were surveyed annually before and after rehabilitation of the gully. The gully cross section measurement was made in May before the start of the rainy season and in October at the end of rainy season. Finally, to measure the change in channel morphology (depth, width and length) erosion pins were installed at regular intervals at each side of the gully system. Sediment concentration data were collected from July to November for two years (2022 and 2024) (Plate 2).

The biomass data of newly emerged vegetation was collected using a quadrant of 50cmx50cm plot to identify the rehabilitation potential of the gully area. Data on soil deposit was collected during the rainfall season for two years.

Plate 2: Picture taken during community training

Capacity Building

Training was given to trail farmers head of woreda agricultural and natural resource management office, experts and IFAD focal, kebele experts in Dollo scheme sites, basically on the effect of elephant grasses with stone check dam on reducing soil erosion, and rehabilitation of gully. The selected gully rehabilitation measures were discussed (i.e). the practices were presented using understandable descriptions in the local language and confirmed by the participants). The advantages and disadvantages of each gully rehabilitation measure were identified from the perspective of the local communities. Fore rating each practice or intervention as very high, high, medium very low and low (Plate 3).

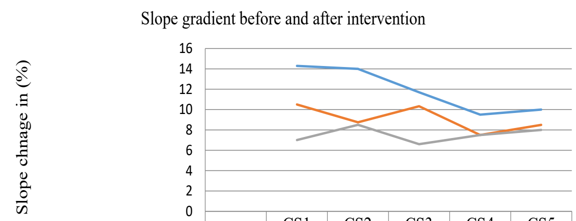
Plate 3: Constructing check dam by community participation

RESULT AND DISCUSSION

Effect of Gully Rehabilitation Measure on Gully Cross-section

Stone check dame integrated with Elephant grass were constructed based on recommended specification together with active community participation to rehabilitate the gully started from 2022 up to 2024. Due to locally available grass were used in the study area. Local community considering their financial and technical capacity can easily manage the gully rehabilitation measures. In gully rehabilitation vegetative materials like Elephant grass is very good stabilizers [22]. The study result demonstrates the way of implementing gully control measures using locally available measures and it was promising. Additionally the study brought a change in farmer's attitude regarding the possibility of reclaiming gully using locally available materials. The result showed that gully cross-sectional channel decreased the gradient slow flow run-off that leads sediment materials deposited and encouraged regenerating vegetative resource at the end of sodding gully channels.

Slope Gradient of Gully Bed: As shown in the Figure 2, below the slope of gully bottom was generally decreased due to rehabilitation measures. In 2022 the initial slope of the channel was 14% after rehabilitation it reduced to 7%. This indicates that, in all gully cross-sections the slope were reduced due to construction of check dams which was integrated by locally available vegetative measures like Elephant grass to rehabilitation of gullies by locally available vegetative measures. As compared for two consecutive trial years the slope of gully bottom under check dames was highly decreased. The slope of gully due to rehabilitation using check dam were reduced 60 %, 46 % 37% respective years [23].



	CS1	CS2	CS3	CS4	CS5
slope Before intervention (2022)	14.29	14	11.7	9.5	10
slope Change in (2023)	10.5	8.75	10.33	7.5	8.5
slope Change in (2024)	7	8.5	6.6	7.5	8

Figure 2 : Slope gradient before and after intervention

Depth of Gully: The depth of gullies was greatly reduced due to implemented rehabilitation measures as time goes on relative to the initial year [Figure 3]. As compering depth of gully after rehabilitation with the baseline data, it was reduced from 1.15 to 0.656 and 0.473m to consecutive years. Therefore, rehabilitating gullies with check dams integrated with locally available vegetative materials like elephant grass supported by closing the site to regenerate the vegetation cover, leads the deposition of sediment by reducing the runoff velocity and increasing gully bottom roughness where the sediment to be trapped by the structure as well as the vegetation. It indicates that all cross sections, change of gully depth reduction was higher under integrated elephant grass with check dam in consecutive years. Relative to gully depths measured in 2024, the highest percentage reduction of gully depth was observed from all gully cross-section. In line to this study, Kirubel et al. [24], were reported that after 17 years Check-dam-accumulated soil ranges 0.4-1.5m depth and more than 1.5m soil was deposited in the gullies with stone check dams integrated with biological measures at Medego watershed in Tigray, northern Ethiopia.

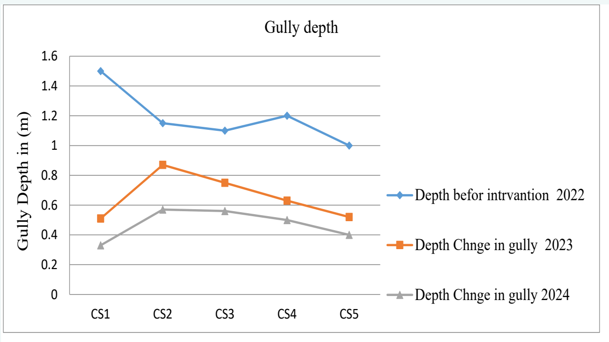


Figure 3 : Gully depths before and after intervention

Gully Width: The result of the study indicates that, width of gully was changed through time to time due to the implementation of check dam integrated with elephant grass. This indicates the activity of gully changes through the year for the implementation of check dam with elephant grass [Figure 4]. The top width of gully profile was decreased from 2.54m, 1.72m and 1.456m at the end of the experiment followed by the control treatment which increases top width by 1m. The study also indicates, the highest bottom width was recorded from treated gully which increases by 2.54m. This indicates that greater sedimentation with in gully bed while more erosion was from gully bank as width of treated gully increase while depth reduced as time goes on from 2022 to 2024.

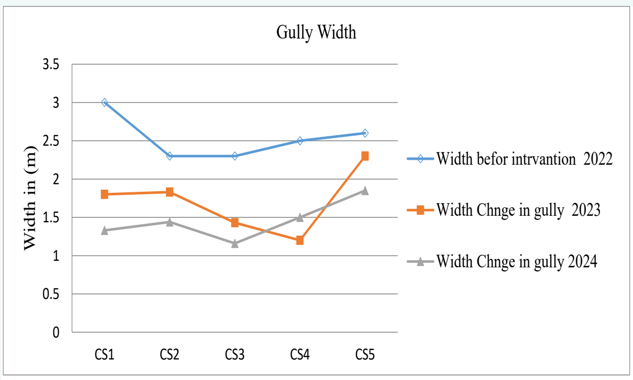


Figure 4 : Gully widths before and after intervention

Gully Volume and Soil Erosion

The eroded volume of gully was calculated using cross sectional and its longitudinal length. Based on result the volume of gully was decreased from time to time as compared with the initial year of implemented rehabilitation measures. Thus, before intervention the volume of gully was 21.019m^3, where as in 2023 and 2024 volume of gully was reduced to 7.05 m^3 and 4.5m^3 respectively. As Compared with the initial gully volume, construction of check dame across the gully bed reduced by 37.44 m^3, 8.81 m^3 and 4.32m^3 for two respective years. Gully Volume directly affected by gully length and gully cross-sectional area. Gully volume is predicted by the catchment area and length of gullies [25], which is the volume of soil lost by gully erosion. Thus, the higher the catchment area of the gully and length of gully leads the higher gully volume keeping were other factors constant.

Effect of Gully Rehabilitation on Sediment Concentration

Before rehabilitation the highest soil loss was observed, however after the intervention the lowest soil loss was recorded from stone check dame with elephant grass. The result indicates that amount of soil deposited were increased from time to time. Stone check dame is effective gully rehabilitation methods, as they reduce sediment lost by gullied. Similarly [26], stone check dam constructed in the gully bed reduced the original gully gradient; finally reduce the eroding power of runoff.

Gully treated with elephant grass and stone check dame had deposited 73.1 ton ha-^{1} yr^{-1} in 2024. This indicates that the implemented integrated gully rehabilitation measures was, to enhanced vegetation cover of the catchment area as well as the gully profile, were effective in trapping the eroded sediment from the catchment area of the respective gully. The result shows that after treated gully bank the highest sediment deposited behind was measured. This is equivalent to (158.938 kg, in 2015 and 183.608 kg in 22024) with bulk density of 1.14, and 1.082 g/cm^3 in respective years. In the other comparison Cross-Section One (CS1) with 9.6m length compered after two years implementation bank and head protection, shows change in gully average width of 1.8m (equivalent to 210.2 and 248.41kg of soil with a bulk density of 1.24 and 1.16g/cm^2) in Table 3. As observed in the filed monitoring and repeated pictures, the control measure was efficient in trapping sediment and free drainage of surface flow (Plate 4). Similar results were reported in the Debre-Mawi watershed that, the implementation of rehabilitation techniques can reduce downstream sediment concentration [27].

Table 1: Baseline data on gully cross sections taken before implementing rehabilitation measure

No of Check dame	Depth (m)	Width (m)	Length (m)	Slope (%)
CS 1	1.30	3	10.28	14.29
CS 2	1.15	2.30	9.8	14
CS 3	1.10	2.30	11.28	11.7
CS 4	1.20	2.50	9.5	9.5
CS 5	100	2.60	9.67	10

Plate 4: Pictures taken sediment deposit behind the check dame

Table 2: Gully Volumes

Gully cross section	2022				2023				2024			
	Depth (m)	Width (m)	Length (m)	Volume (m^3)	Depth (m)	Width (m)	Length (m)	Volume (m^3)	Depth (m)	Width (m)	Length (m)	Volume (m^3)
CS1	1.3	3	9.6	37.44	0.51	1.8	9.6	8.8128	0.33	1.33	9.6	4.321
CS2	1.15	2.3	4.4	11.638	0.87	1.83	4.4	7.00524	0.57	1.44	4.4	3.611
CS3	1.1	2.3	4.3	10.879	0.75	1.43	4.3	4.612	0.56	1.16	4.4	2.7939
CS4	1.2	2.5	9.5	28.5	0.63	1.2	9.5	7.182	0.5	1.5	9.5	7.125
CS5	1	2.6	6.4	16.64	0.52	2.3	6.4	7.6544	0.4	1.85	6.4	4.376
Mean	1.15	2.54	6.84	21.019	0.65	1.71	6.84	7.053	0.47	1.45	6.84	4.495

Table 3: Sediment concentrations

	2023				2024			
Gully cross sections	Volume (cm^3)	BD g/cm^3	Area (m^2)	Massof trapped Sediment (kg)	Volume (cm^3)	BD g/cm^3	Area (m^2)	Mass of trapped sediment (kg)
CS1	13.6512	1.24	12.28	210.2	12.38496	1.16	12.76	248.41
CS2	2.25456	0.957	8.052	111.2	3.67488	0.97	6.336	183.8
CS3	2.15215	1.264	6.149	137.1	2.69352	1.14	4.988	154.5
CS4	6.498	1.121	11.4	131.58	9.975	1.09	14.25	181.7
CS5	7.0656	1.11	14.72	166.4	7.104	1.05	11.84	187.24
Mean	6.32430	1.1384	11.71	158.938	7.166472	1.082	9.96	183.608

Effect of Gully Rehabilitation on Grass Biomass

The result showed that Elephant grass is fast-growing, easy to establish, drought resistance, reduce soil erosion and higher harvesting frequency. The highest fresh weight biomass data were produced from elephant grasses due to their rapid growth rate. Biomass production already during the rainy season is astonishing. The role of vegetative cover is to intercept rainfall, to keep the soil covered with litter, to maintain soil structure and pore space, and to create openings and cavities by root penetration. In general, it management and protection rather than the type of the vegetative cover which determines its effectiveness in gully control. Any vegetation which is well-adapted to local conditions and which shows vigorous growth may be used. Whenever possible, it is desirable to establish a vegetative cover which serves a dual purpose, for example, provision of fodder, fuel wood and fruit. Sedimentation occurs and increases as the shoot growth forms a dense barrier that disturbs and breaks the velocity of the water. This leads to a gradual build-up of the gully floor.

Farmers Perception on Gully Rehabilitation Method

Drivers and Effect of Gully Formation: According to FGD gully usually formed in upstream area and took the form of rill erosion. Over time the rill got longer and deeper in the mid slope land scape to form gullies. The key informants identified multiple human induced, natural and climatic drivers of gully erosion and formation. As shown the Table 4 below the respondents believed that absence of protection measure that was the most significant cause of soil erosion followed farmers who considered that deforestation, improper farming and topography was also the most important major cause. Aklilu and Graaff [28], indicated that, farmers expressed the opinion that the inappropriate land use causes soil erosion by water in Ethiopia's highland areas Beressa watershed in the central highlands of Ethiopia.

Identified impact suggests that gully erosion has both long and short-term negative impact that affect the livelihood of local community. Additionally the discussant perceived that, the major cause of gully formation are absence of protection measures, deforestation, improper farming and erratic rainfall whereas a negative consequences of gully formation were loss of land productivity, soil loss increments, destruction of farm land, decline soil fertility and reduction of soil depth [Table 5]. This result is similar with the findings of Nyssen et al. [29], who 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 reduction in central highland.

Farmer's Perception Towards Gully Rehabilitation and Integration Work with Stakeholders: During FGD majority of participants have elaborated that, there is no collaboration work on gully rehabilitation with the community before Arba Minch research center had intervene in the area. Majority of respondents have no

Table 4: Farmers' perception on major drivers and effect of gully

Derivers	Ranking	Effect of gully formation	Ranking
Absence of protection measures	1	Reduce soil depth	4
Deforestation	2	Decline soil fertility	3
Improper farming system	3	Destruction of farm land	5
Topography	5	Loss of land productivity	1
Erratic rainfall	4	Increased soil loss	2

Table 5: Perception on responsible body to gully

Responsible body to control gully	Farmers perception ranking
NGOs	3
Community mobilization	1
Individuals	2

understanding on gully rehabilitation practices on their farm land but few that understood and practice on that farm land. The discussant was also mentioned that Agricultural and rural office needs to work on awareness creation formation and consequence of gully, mobilize and initiatives the community and disseminate the information to participate on rehabilitation work. This finding indicated that research science based development with integration multi-institutional is the best approach community based participatory gully rehabilitation in study area. Similar approach was reported by Water and Land Resource Centre [30].

Perception on the Implemented Gully Rehabilitation Measure: In the study area all group discussant perceived that there is moderate dynamics gully erosion problem on their farm land, this problem is highly decreased after rehabilitation of gully. Gully control measures are based on the size of the gully catchment area, gradient and length of the channel and arability of materials. These respondents further elaborated that the rehabilitation measures reduced soil erosion, reduced velocity of run off, minimize gully development and converted degraded land to productive lands [Table 6]. Particularly gully rehabilitation measures supported restoration of degraded lands in several ways, including through reducing expansion and upward expansion gullies, reducing runoff and soil loss. This agrees with previous works FAO [31].

In gully rehabilitation methods, elephant grass barriers was very good stabilizer. The key role of gully rehabilitation measures in reducing runoff and soil loss. The capacity of this measure was attributed to reduce speed of runoff, retain soils and facilitate growth of grass in the retained soil. This result is similar with the findings of Nyssen et al. [32], studies, and at Ethiopian highlands indicated that the development of gullies has led to an enlarged drainage, resulting in soil loss and a corresponding crop yield reduction in central high land.

Table 6: Farmer's perception on the implemented rehabilitation measure

Effect of rehabilitation measures	Farmers perception ranking
Soil deposited	3
Reduced runoff velocity	1
Minimized gully development	4
Increase land productivity	2

CONCLUSION AND RECOMMENDATIONS

Based on the results the study concluded that comparison result between gully before and after rehabilitation over gully bank result shows a significant change in sediment production. Gully bed plantation integrated with stone check dame is more effective gully erosion control methods. Changes in the depth, width, gradient, and biomass from harvested grass were observed after the intervention. These changes were caused by the implementation of gully rehabilitation techniques, which included planting forage grass and building a small stone check dams. These changes also helped farmers make money by reducing sediment loss. Based on the study's findings, we came to conclude that farmers should use gully rehabilitation techniques to preserve their land. Based on the findings of the study land degradation via the gully erosion is worsening throughout the years; therefore all stakeholders need to apply sustainable and participatory natural resource management. And also Ones gully are formed huge investment are required to rehabilitate the gully, so farmers should use gully rehabilitation techniques to preserve their land.

REFERENCES

1. Tsimi C, Ganas A, Dimoyiannis D. Catchment-wide estimate of single storm inter rill soil erosion using an aggregate instability index: a model based on geo- graphic information systems. Nat Hazards. 2012; 62: 863
2. Frankl A, Nyssen J, De Dapper M, Haile M, Billi P, Munro RN, et al. Linking long-term gully and river channel dynamics to environmental change using repeat photography (Northern Ethiopia). Geomorphology. 2011; 129: 238-251,
3. Dagnew CD, Guzman AD, Zegeye TY, Tibebu M, Getaneh S, Abate FA, et al. Steenhuis, Impact of conservation practices on runoff and soil loss in the sub-humid Ethiopian Highlands: The Debre Mawi watershed. J Hydrol Hydromechanics. 2015; 63: 214-223.
4. Cheng H, Zou X, Wu Y, Zhang C, Zheng Q, Jiang Z. Morphology parameters of ephemeral gully in characteristics hill slopes on the Loess Plateau of China, Soil Tillage Res. 2007; 94: 4-14
5. Were K, Kebeney S, Churu H, Mutio JM, Njoroge R, Mugaa D, et al. 600 Spatial Prediction and Mapping of Gully Erosion Susceptibility Using Machine Learning Techniques in a Degraded Semi-Arid Region of Kenya, Land. 2003; 12.
6. Food and Agricultural Organisation (FAO): Production yearbook. Rome: FAO. 2001.
7. Frankl A, Poesen J, Scholiers N, Haile M, Deckers J, Nyssen J. Factors controlling the morphology and volume (V) – length (L) relations of permanent gullies in the northern Ethiopian Highlands. 2013; 16: 1672-1684
8. Poesen J, Vandekerckhove L, Nachtergaele J, Oostwoud Wijdenes D, Verstraeten G, Van Wesemael B. Gully Erosion in Dry land Environments. In Dryland Rivers: Hydrology and Geomorphology of Semi- Arid Channels, Bull LJ, Kirkby M J (eds). Wiley: Chichester. 2002; 229-262.

9. Nyssen M, Veyret-Picot J, Poesen J, Moeyersons M, Haile J. Deckers, Govers G. The effectiveness of loose rock check dams for gully control in Tigray, northern Ethiopia. Soil Use and Management. 2006; 20: 55-64

10. Belayneh L, Bantider A, Moges A. Road construction and gully development in Hadero Tunto–Durgi Road project, southern Ethiopia. Ethiopian J Env Stu Mgt. 2024; 7: 720-730

11. Cohen MJ, Brown MT, Shepherd KD. Estimating the environmental costs of soil erosion at multiple scales in Kenya using emerge synthesis. Agric Ecosystem Environment. 2006; 114: 249-269.

12. Mekuria W, Gedle A, Tesfaye Y, Phimister E. Implications of changes in land use for ecosystem service values of two highly eroded watersheds in Lake Abaya Chamo sub-basin, Ethiopia. Ecosyst Serv. 2023.

13. Adimas N, Mekonnen M, Tsegaye D, Senamaw A. Gully Erosion and Effectiveness of its Treatment Measures, Upper Abay Basin, in the Northwest Highlands of Ethiopia. Nile and Grand Ethiopian Renaissance Dam: Past, Present and Future. 2021; 397-421.

14. Alem B. The nexus between land use land cover dynamics and soil erosion hotspot area of Girana Watershed, Awash River Basin, Ethiopia, Heliyon. 2022; 8

15. Degife A, Worku H, Gizaw S. Environmental implications of soil erosion and sediment yield in Lake Hawassa watershed, south-central Ethiopia. Environ Syst Res. 2021; 3: 1-24.

16. Dagnew CD, Guzman AD, Zegeye TY, Tibebu M, Getaneh S, Abate FA, et al. Steenhuis, Impact of conservation practices on runoff and soil loss in the sub-humid Ethiopian Highlands: The Debre Mawi watershed. J Hydrol Hydromechanics. 2015; 63: 214-223.

17. Poesen J, Nachtergaele J, Verstraeten G, Valentin C. Gully erosion and environmental change: importance and research needs, Catena. 2003; 50: 91-133.

18. Nasri M, Feiznia S, Jafari M, Ahmadi H. Using field Indices of rill and gully in order to erosion estimating and sediment analysis (case study: Menderjan Watershed in Isfahan Province, Iran. Int J Environ Eng. 2008; 2: 69-75

19. Blake WH, Rabinovich A, Wynants M, Kelly C, Nasseri M, Ngondya I, et al. Soil erosion in East Africa: an interdisciplinary approach to realising pastoral land management change. Environ Res Lett. 2018; 13:

20. Rabinovich A, Zhischenko V, Nasseri M, Heath SC, Laizer A, Mkilema F, et al. Informing versus generating a discussion: Comparing two approaches to encouraging mitigation of soil erosion among Maasai pastoralists. J Environ Psychol. 2022; 84: 101885.

21. Barvels E, Fensholt R. Earth observation-based detectability of the effects of land management programmes to counter land degradation: A case study from the highlands of the Ethiopian Plateau. Remote Sens. 2021; 13.

22. Nyssen M, Veyret-Picot J, Poesen J, Moeyersons M, Haile J. Deckers, Govers, The effectiveness of loose rock check dams for gully control in Tigray, northern Ethiopia. Soil Use and Management, 2006; 20: 55-64.

23. Addisie MB, Alebachew A., Ayele GK, Tilahun SA., Hailu N, Mekuria W, Landgandoenc E, Steenhuisad TS. (2015). Low-cost measures can reclaim gullies and reduce soil erosion in the Ethiopian highlands (No. 04; WLE Technical Briefing Series). 2015.

24. Kirubel M, Gebreyesus BT. Impact assessment of soil and water conservation measures at Medego watershed in Tigray, northern Ethiopia. Maejo Int J Sci Technol. 2011; 5: 312-330.

25. Frankl A, Poesen J, Scholiers N, Haile M, Deckers J, Nyssen J. Factors controlling the morphology and volume (V) – length (L) relations of permanent gullies in the northern Ethiopian Highlands. 2013; 16: 1672-1684.

26. Addis HK, Adugna B, Gebretsadik M, Ayalew B. Gully morphology and rehabilitation measures in different Agro ecological environments of Northwestern Ethiopia. Applied and Environmental Soil Science. 2015; 1-8.

27. Dagnew CD, Guzman AD, Zegeye TY, Tibebu M, Getaneh S, Abate FA, et al. Steenhuis, Impact of conservation practices on runoff and soil loss in the sub-humid Ethiopian Highlands: The Debre Mawi watershed. J Hydrol Hydromechanics. 2015; 63: 214-223.

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

29. Frankl A, Nyssen J, De Dapper M, Haile M, Billi P, Munro RN, et al. Linking long-term gully and river channel dynamics to environmental change using repeat photography (Northern Ethiopia), Geomorphology. 2011; 129: 238-251.

30. Water and Land Resource Centre 2015. Learning Watershed. An Approach for Participatory Integrated Water and Land Resources Management and Livelihood. 2015.

31. FAO.Watershed management field manual Gully control. FAO Conservation Guide 13/2. 1986..

32. Nyssen M, Veyret-Picot J, Poesen J, Moeyersons M, Haile J, Deckers. The effectiveness of loose rock check dams for gully control in Tigray, northern Ethiopia. Soil Use and Management. 2006; 20: 55-64.