Science Research
2024; 12(1): 1-8
http://www.sciencepublishinggroup.com/j/sr
doi: 10.11648/sr.20241201.11
ISSN: 2329-0935 (Print); ISSN: 2329-0927 (Online)

Participatory Integrated Low-Cost measures Gully Rehabilitation and Reclamation for Sustainable Land Management in Ilasa Watershed of Goba Distinct Bale Zone

Mulugeta Eshetu[*], Daniel Abegeja, Tesfaye Ketama, Girma Getachow, Regassa Gosa

Oromia Agricutural Research Institute, Sinana Agriculture Research Center, Soil Fertility Improvement, Soil and Water Conservation, Watershed Management Research Team, Bale-Robe, Ethiopia

Email address:
mulugeteshetu@gmail.com (Mulugeta Eshetu)
[*]Corresponding author

To cite this article:
Mulugeta Eshetu, Daniel Abegeja, Tesfaye Ketama, Girma Getachow, Regassa Gosa. (2024). Participatory Integrated Low-Cost measures Gully Rehabilitation and Reclamation for Sustainable Land Management in Ilasa Watershed of Goba Distinct Bale Zone. *Science Research*, *12*(1), 1-8. https://doi.org/10.11648/sr.20241201.11

Received: December 17, 2023; **Accepted**: January 15, 2024; **Published**: February 5, 2024

Abstract: Since gully erosion is generated by surface runoff and further enhanced by rough terrain and human-induced variables, it poses a severe danger to the World. The severe and enduring problems for the environment and livelihood in the study area were gully extension and land degradation. The aim of the study was to characterize gulley morphology and evaluate participatory integrated low-cost gully rehabilitation and reclamation techniques for sustainable land management in the Ilasa watershed of Goba distinct Bale highland. The study was carried out in collaboration with the local community to ensure reduced expenses associated with gully reclamation and improved efficacy of gully rehabilitation strategies. Several gully morphological characterizations and reshaping were conducted to evaluate the effectiveness of the structures. Finally, based on standard soil and water conservation measures physical structures integrated with biological measures were implemented, with various materials readily available locally to reduce the severity of the gulley. The results showed that as gully morphologies classifications standards, the study's area was moderately to severely deteriorate. Prioritizing the rehabilitation and restoration of gullies through morphological assessment, perception collection of data, identification of locally available, low-cost materials, and slope-based implement structures might greatly minimize sediment losses. Reshaping gullies and constructing a check dam with a cut-off drain at the head of the gully to reduce sediment loss and another gullies' branch developments aid in reclamation were more successful strategies. The participatory working with local communities to reclaim gullies could help change farmers' perceptions and uses of low-cost locally available materials to enhance the effectiveness of gully rehabilitation measures which supports farmers' implementation at early stages. Further study on alternative gulley rehabilitation through discharge monitoring and sediment loss in the watershed from different perspectives is advisable to sustainably satisfy the benefits of the community and the viability of natural resources.

Keywords: Soil Erosion, Gulley Morphologies, Locally Available Materials, Gulley Rehabilitation

1. Introduction

Water erosion is the leading source of land degradation throughout the globe [23, 7, 5]. The global food supply and the protection of the environment are at risk due to soil erosion caused by water [17, 10]. Extreme runoff, the highest intensity of rainfall, and soil erosion are all characteristics of the watershed that cause land degradation [8, 11]. Soil erosion may take several forms, including gullies, sheets, and rills. These kinds of erosion have resulted in the loss of thousands of hectares of productive agricultural land national. Gully erosion is one of the world's most serious environmental problems [1, 2].

Gully erosion represents the most severe stage among all soil erosion types. It is a highly apparent erosion that influences different soil functions, including soil fertility, water storage, agricultural land, human physical and cultural environment, and raw material sources. In particular, on sloping areas used for agriculture, preventing soil erosion via appropriate soil and water conservation (SWC) methods should be a top priority to achieve sustainable land uses. At different points over the century, Ethiopia has employed various SWC measures [13, 14, 20].

Investments in soil and water conservation (SWC) practices enhance crop production, food security, and household income [3]. Selecting appropriate gully rehabilitation measures with locally available materials integrating with biological measures has significant importance in areas with subsistence farmers where gully erosion is much more severe gully erosion.

Different techniques, such as sediment traps, check dams, rock fills, or breakwaters that lower the channel bed's slope, have been used to restoration degraded areas damaged by gully erosion [4, 6, 12]. In sites where gully erosion is severe, choosing suitable gully rehabilitation techniques using locally accessible materials and combining them with biological treatments is crucial. Hence, the study aimed to characterize gulley morphology and evaluate the efficacy of participatory integrated low-cost approaches for gully rehabilitation and reclamation.

2. Material and Methods

2.1. Description of the Study Area

Goba district is located in Bale Highland, Oromia Regional State of Ethiopia. It is located 445 kilometers from Addis Ababa, the capital city of Ethiopia (Figure 1). The Goba district is a highland area characterized by mountain ranges, plains, rocky areas, and gorges. The minimum temperature is 4°C, and the maximum temperature is 25°C. The two rainy seasons in the Goba area are summer and spring (bimodal rainfall). The district's economy is based on agriculture, which employs nearly all residents. The area's productivity and production are severely hindered by soil erosion, gully expansion, and agricultural land loss. The Ilasa watershed is geographically situated between 6°57′30″ and 7°0′30″ North and 40°3′ 30″ and 40°6′0″ east. Its height varies from 2462 to 2991 above mean sea level (Figure 1). The study area covers a total area of 506 hectares.

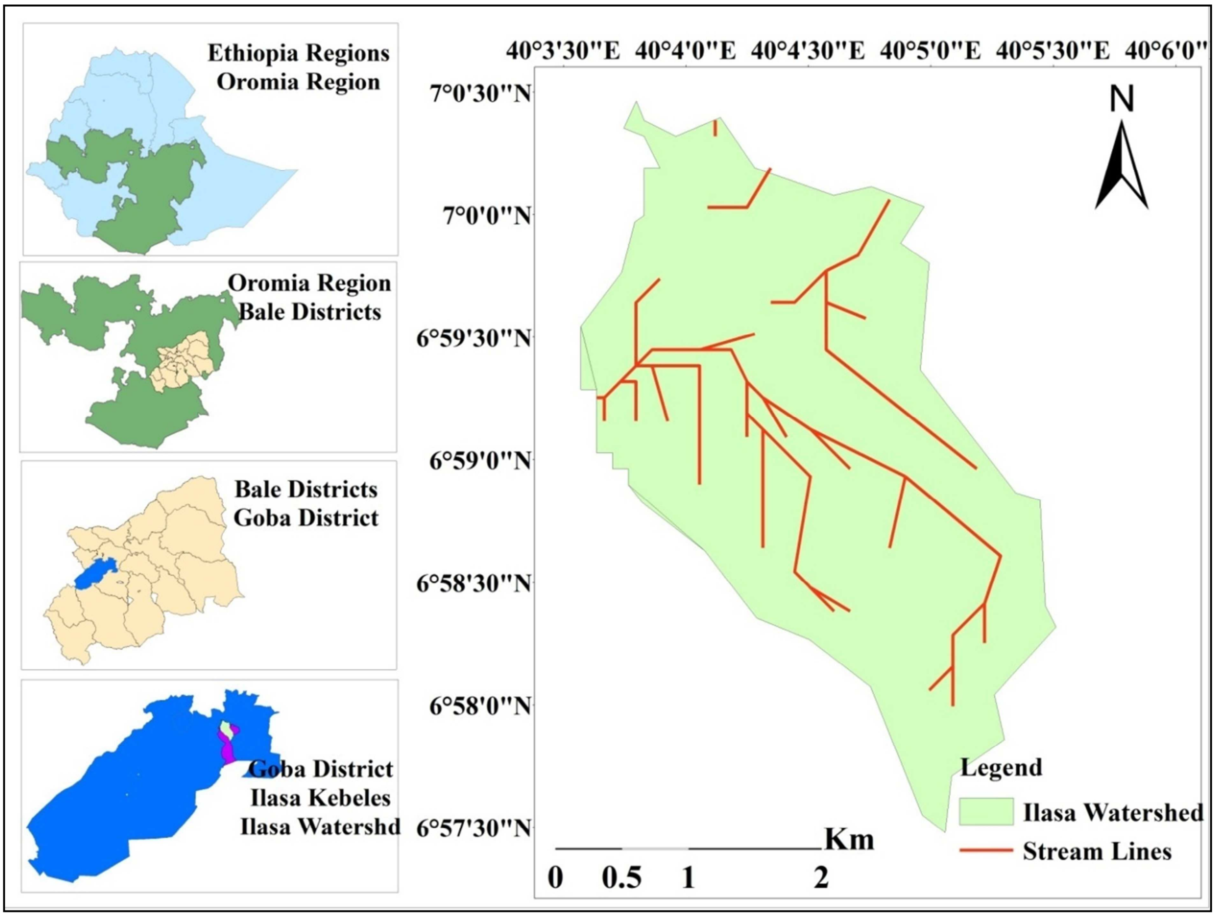

Figure 1. *Map of the study site.*

2.2. Topography and Slope Characteristic

The influences of length and steepness on a slope determine how topography affects land degradation. Runoff rate and velocity are determined by the drainage area's size, shape, and overall slope [21]. According to [16] recommendations for SWC structure implantation and layout, the slopes were classified into five (5) classes: flat or nearly flat (0–3%), gently sloping (3–8%), sloping (8–15%), moderately steep (15–30%), and steep (30–50%), as shown in figure 2.

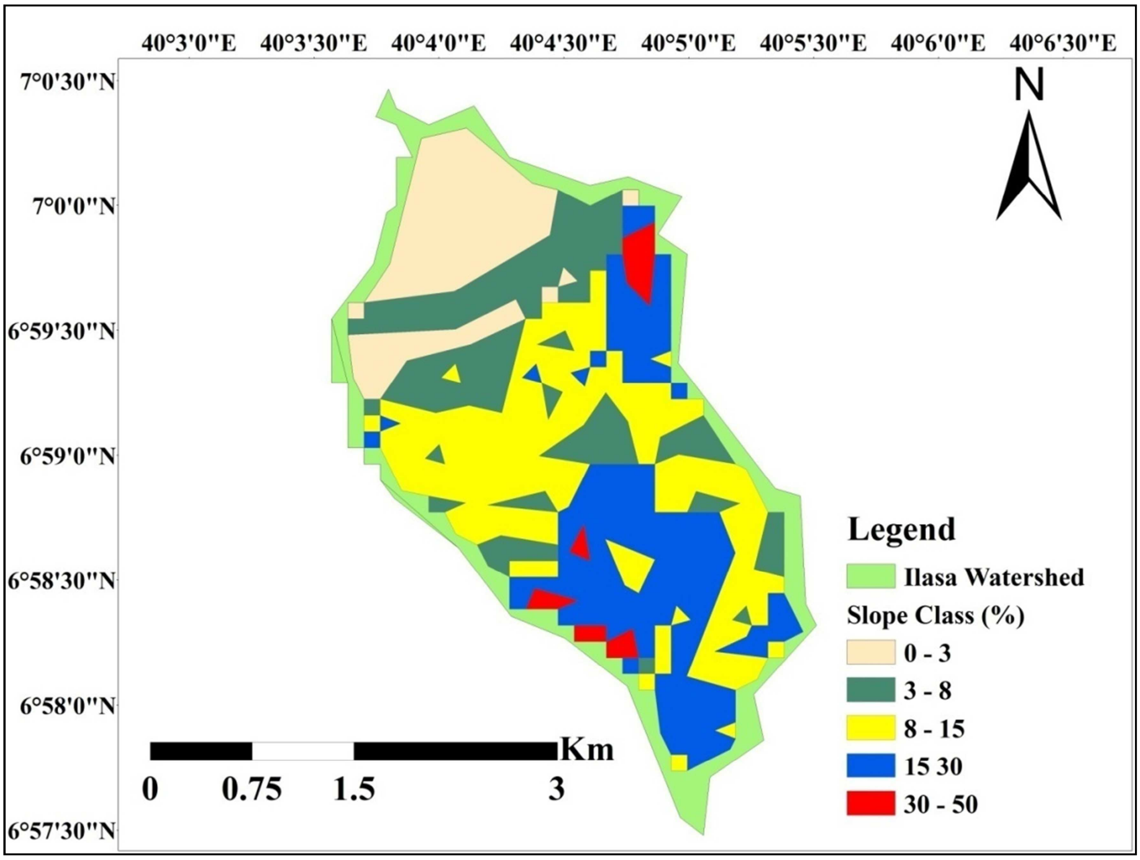

Figure 2. *Slope Classes of Ilasa Watershed.*

2.3. Climate

The Goba district has two distinct seasons (bimodal rainfall): the relatively brief dry season, which lasts from December to February, and the lengthy wet season, which runs from March to November. There is a seasonal bimodal rainfall distribution rainfall in the area with average monthly precipitation. The rainfall distribution in the area alternates between moderate rainfall in June, November, March, and May, and average monthly minimums in December, January, and February. In contrast, the average maximum rainfall in October, July, April, September, and August is between 102.5 and 155.5 ml. The study area has monthly maximum temperatures between 20.5C - 24.3C and lowest temperatures between 5.2C - (-10.0C). January had the lowest temperature ever recorded, while July had the highest.

2.4. Soil and Vegetation

Chromic, Pellic Vertisols, and Luvisols are the three soil types in the Ilasa watershed. The vegetation grown in the watershed are Juniperus procera, Eucalyptus, Olea europace, Hagenia Abyssnica, cordial africana, suppresses, and various shrubs and bush encouragement. However, these indigenous trees are vulnerable to deforestation because of fuel, building, and agricultural expansions [21].

2.5. Community Participation; Approach and Activities Innervations

The engagement of local communities in watershed management initiatives through awareness creation, training, labor payment in the form of incentives, organizing FRG and watershed use associations, and providing materials (such as wood and gabions) for soil and water conservation measures all of which are essential to the program's success.

2.6. Gullies Morphologies Sampling and Analysis

The width and length of each gully were measured, along with the slope of each gully, using the head cut, 50% of the gully's length, and the bottom. Physical characteristics (cut shape and stage) of every gully were measured, along with the primary causes of the gullies' emergence and the mitigation measures implemented. A total of 22 gully samples using random sampling methods were selected at three slope categories (upper, middle, and lower slope positions). Descriptive statistics were employed to compare the relationship between each gully morphological characteristic.

2.7. Gully Reclamation Approach and Mode of Conducted

The excavation was conducted at the foot of the gully heads to provide an appropriate platform for the structures planned for reclamation and rehabilitation of the constructed gullies. The head gullies were formed with various locally accessible materials at a 45-degree angle without causing any disturbance to the side banks. By providing financial, technical, and capacity-building support, as well as creating awareness to facilitate the management of the gully restoration procedures, participatory integrated watershed approaches were used to guarantee local populations' engagement.

2.8. Layout and Construction of Gulley Intervention Measures

These studies considered soil types and slopes in addition to the recommendations of the [16, 19] guidelines for soil and water conservation implementation. Finally, the Ilasa watershed's constructed soil and water conservation structures have been described as follows.

Gully reshaping and filling: Gully wall reshaping involves digging tiny trenches along contours and chopping down steep slopes of active gully edges to a moderate slope (minimum at 45% slope). This process can go up to two-thirds of the gully's total depth.

Check-dams: To prevent channel/bed erosion, check-dams were constructed across the gully bed. Check-dams reduce runoff's erosive force and water flow velocity by lowering the gully channel's initial gradient (Figure 3).

Cut-off Drain: Soil and water conservation measures minimum standards for gradient, such as 0 to 5% maximum without scour tests, were followed in the construction of the cut-off drain. A minimum of 0.5 meters at the top width, all slopes cut to a grade of 1 to 1, and scour checks (for gradients of 1 to 2%); shape: Parabolic or trapezoidal.

Stone Check-dam: Based on minimum standards for soil and water conservation measures different stone Check-dams were constructed such as spacing estimated on the safe side using S (spacing) m = Height (m) x 1,2/ Gradient (in decimals); Side key: 0,7-1 m inside gully sides, Bottom key & foundation: 0,5m depth x width of check dam; Height: min 1m and max 1,5 m excluding foundation; Base width: min 1,5 and max 3,5 m (Figure 3).

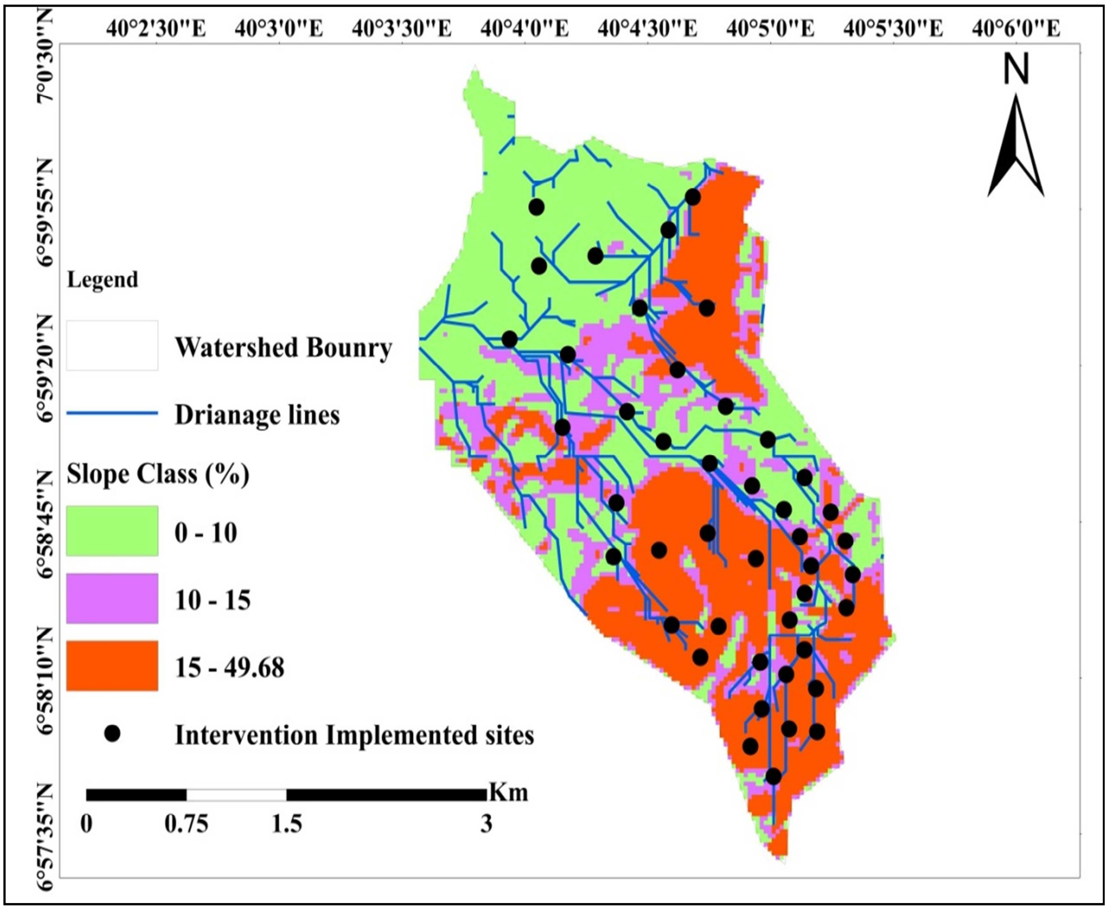

Figure 3. *Interventions implemented points.*

3. Results and Discussions

3.1. Characteristics of Gullies Morphology

3.1.1. Gully Depth

The gully classification method was based on depth characterizes small, medium, and large gullies as per the norms routinely used in various soil and water conservation publications. Therefore based on gully depth gullies were categorized as small gully (< 1.5 m), medium gully (1.5 to 3 m), and large gully (> 3 m) (Table 1). Likewise, [22] used a similar rate for classifying gullies.

Table 1. *Gulley morphology characterization at Ilasa watershed.*

Gulley Class	Min (m)	Max (m)	Average(m)	StdDev
Small gully	0.05	1.30	0.73	0.44
Medium Gully	1.80	2.22	1.97	0.18
Large gully	3.60	8.00	5.38	1.88

3.1.2. Gully Length

In the Ilasa sub-watershed, the maximum and minimum gully lengths were 600 and 210 meters, respectively, with a standard deviation of 122.46 meters and a mean of 356.68 meters (Table 2). Table 2 also reveals the estimated mean values for the top and bottom gully widths, which were 5.20 and 4.69 meters, respectively, with standard deviations of 4.64 and 4.61 for top width and bottom width; respectively.

3.1.3. Gully Surface Area

The total surface area occupied by gullies in the Ilasa sub-watershed showed high variation in which the minimum (0.05 m^2), and maximum (15.73 m^2) with mean values of 15.73 m^2 and a standard deviation of 24.07 (Table 2). This shows that the gullies in the area have greatly vary in their most gully morphological parameters.

Table 2. *Statistical description of gullies morphologies at Ilasa watershed.*

Gullies Morphology	N	Min (m)	Max (m)	Mean	Std. Error	Std. Deviation
Length (m)	22	210	600	356.68	26.11	122.46
Depth (m)	22	0.05	8.00	2.22	0.48	2.26
Top Width (m)	22	0.50	21.00	5.20	0.99	4.64
Bottom Width (m)	22	0.48	20.48	4.69	0.98	4.61
Gully surface area (m^2)	22	0.050	96.00	15.73	5.13	24.07

3.2. Training and Awareness Creation

Finally, the view of farmers regarding the feasibility of recovering gullies using inexpensive, locally sourced materials was altered by our study. Before the implementation of gully intervention strategies, farmers in the research region held the belief that "it is impossible to stop the formation and development of gullies" and that "the formed gullies are beyond our capacities, untreated with locally available materials." But after carrying out this study in coordination with the local community, specialists and development representatives were persuaded that gullies might be recovered and turned into useful land.

In rural communities, raising awareness, developing skills, and enhancing community involvement are crucial to sustainable integrated watershed management. This is especially true for the Goba district's Ilasa watershed, which has severe issues with land degradation and soil erosion [21].

Table 3. *Training and capacity building on gullies at Ilasa watershed of Goba Districts.*

Years	Experts		DA	Farmers		Total
	M	F	M	M	F	
2016	3	1	2	30	17	53
2017	4	1	4	140	60	209
2018	2	1	2	50	40	95
2019	1	-	3	50	50	104
2020	3	1	2	30	26	62
2021	2	1	1	50	46	100
Total	15	5	14	350	239	623

A total of 473 people were included in the program to strengthen the capacity of watershed management to promote sustainable natural resource management at the Ilasa watershed through participatory means the research places greater emphasis on training and discussions with various stakeholders about technical and practical training as well as experience sharing of model practices.

Out of the total 306 male participants and 167 female participants, respectively, were mentioned in Table 3 and figure 4. Farmers were encouraged to participate in watershed management and household skill improvement, and the role and connections of women in these intervention works were raised by this strategy, which also improved farmers' perceptions of the socioeconomic pillars that SWC measures provided.

Figure 4. *Picture during community based participation rehabilitation work at Ilasa watershed.*

3.3. Soil Organic Matter and Total Nitrogen

The average amount of soil organic matter (OM) measured following the intervention (3.704 %) was higher than that measured before the intervention (1.298 %) (Table 4). Improvements in soil organic matter may be responsible for this since it reduces soil erosion and replenishes plant nutrients. Table 4 shows that the total nitrogen (TN) level measured following the intervention (0.184%) was higher than the amount measured before the intervention (0.066%). The organic matter buildup in the preserved field might explain this.

Table 4. *Soil chemical properties before and after interventions.*

Site	Before intervention		After Intervention	
	OM (%)	TN (%)	OM (%)	TN (%)
1	1.18	0.06	4.87	0.24
2	1.24	0.06	3.26	0.16
3	1.65	0.08	3.46	0.17
4	1.11	0.06	3.40	0.17
5	1.31	0.07	3.53	0.18
Average	1.298	0.066	3.704	0.184

Figure 5. *Status of land degration and gulley severist at Ilasa watershed before intevation.*

Figure 6. *Ilasa watershed status after innervations.*

4. Conclusion and Recommendations

The study area was classified as a moderate to severely degraded area based on gully morphologies, as per the data obtained from measurement and observation. Identifying low-cost, locally available materials, collecting perception data, and morphologically characterizing gully structures should be priorities before gully interventions.

The gully reshaping, stone and wooden check dam, and cut-off drain supported with biological measures reduced sediment loss and further extension so that more efficient ways to mitigate gully erosion. Participatory approach and use of low-cost locally available materials to restore gullies are the efficacy and affordable gullies measures strategies.

Ethics Approval

The authors acknowledged that they were committed to publication ethics and conducted their study by accepted scientific research ethics.

Conflicts of Interest

The authors declare no conflict of interest.

References

[1] Abdulfatai, I. A., Okunlola, A. I., Akande, W. G., Momoh, L. O. and Ibrahim, K. O., 2014. Review of gully erosion in Nigeria: causes, impacts and possible solutions.

[2] Addis, H. K., Adugna, B., Gebretsadik, M. and Ayalew, B., 2015. Gully morphology and rehabilitation measures in different agro ecological environments of northwestern Ethiopia. *Applied and environmental soil science*.

[3] Adgo, E., Teshome, A., and Mati, B. (2013). Impacts of long-term soil and water conservation on agricultural productivity: the case of Anjenie watershed, Ethiopia. *Agric. Water Manag.* 117, 55–61.

[4] Alfonso-Torreño, A., Schnabel, S., Gómez-Gutiérrez, Á. Crema, S. and Cavalli, M., 2022. Effects of gully control measures on sediment yield and connectivity in wooded rangelands. *Catena*, *214*, 106259.

[5] Bafe Betela and Kebede Wolka. 2021. Evaluating soil erosion and factors determining farmers' adoption and management of physical soil and water conservation measures in Bachire watershed, southwest Ethiopia. *Environmental Challenges* 5; 100348.

[6] Bartley, R., Poesen, J., Wilkinson, S. and Vanmaercke, M., 2020. A review of the magnitude and response times for sediment yield reductions following the rehabilitation of gullied landscapes. *Earth Surface Processes and Landforms*, *45*(13), 3250-3279.

[7] Belayneh M, Yirgu T, Tsegaye D. 2019. Potential soil erosion estimation and area prioritization for better conservation planning in Gumara watershed using RUSLE and GIS techniques'. Environmental Systems Research 8(1): 1-17.

[8] Belayneh, M., Yirgu, T., Tsegaye, D., 2020. Current extent, temporal trends, and rates of gully erosion in the Gumara watershed, Northwestern Ethiopia. Global Ecol. Conserv. 24, e01255.

[9] Borrelli, P., Robinson, D. A., Fleischer, L. R., Lugato, E., Ballabio, C., Alewell, C., Meusburger, C. K., Modugno, S., Schutt, B., Ferro, V., Bagarello, V., Oost, K. V., Montanarella, L., Panagos, P., 2017. An assessment of the global impact of 21st century land use change on soil erosion. Nat. Commun. 8(1), 1–13.

[10] FAO, 2019. Soil erosion: the Greatest Challenge to Sustainable Soil Management. Food and Agriculture of Organization of the United Nations, Rome.

[11] Fazzini M, Bisci C, Billi P. 2015. The climate of Ethiopia. In: Billi P (ed) Landscapes and Landforms of Ethiopia. World geomorphologic landscapes. Springer, Dordrecht.

[12] González−Romero, J., López−Vicente, M., Gómez−Sánchez, E., Peña−Molina, E., Galletero, P., Plaza−Alvarez, P., Moya, D., De las Heras, J. and Lucas−Borja, M. E., 2021. Post−fire management effects on sediment (dis) connectivity in Mediterranean forest ecosystems: Channel and catchment response. *Earth Surface Processes and Landforms*, *46*(13), 2710-2727.

[13] Haregeweyn, N., Tsunekawa, A., Nyssen, J., Poesen, J., Tsubo, M., Meshesha, D. T., Schütt, B., Adgo, E., Tegegne, F., 2015. Soil erosion and conservation in Ethiopia. Progr. Phys. Geogr. Earth Environ. 39, 750–774.

[14] Heri-Kazi, A. B., Bielders, C. L., 2021. Cropland characteristics and extent of soil loss by rill and gully erosion in smallholder farms in the KIVU highlands, D. R. Congo. Geoderma Reg. 26, e00404.

[15] Karamage, F., Zhang, C., Liu, T., Maganda, A., Isabwe, A., 2017. Soil erosion risk assess- ment in Uganda. Forests 8(52), 1–20.

[16] Lakew Desta, Carucci, V., Asrat Wendem-Ageňehu and Yitayew Abebe (eds). 2005. Community Based Participatory Watershed Development: A Guideline. Ministry of Agriculture and Rural Development, Addis Ababa, Ethiopia.

[17] Lieskovsky J, Kenderessy P. 2014. Modelling the effect of vegetation cover and different tillage practices on soil erosion in vineyards: a case study in Vrable (Slovakia) using WATEM/SEDEM. Land degradation and Development 25(3): 288-296.

[18] Mekonen G, Fekadu A. 2015. Experiences and challenges of integrated watershed management in central zones of southern Ethiopia. Int J Curr Res 7(10): 20973–20979.

[19] MoA (Ministry of Agriculture). 2016. Soil and Water Conservation in Ethiopia (Guidelines for Development Agents). Ethiopia.

[20] Mukai, S., Billi, P., Haregeweyn, N., Hordofa, T., 2021. Long-term effectiveness of in- digenous and introduced soil and water conservation measures in soil loss and slope gradient reductions in the semi-arid Ethiopian lowlands. Geoderma 382, 114757.

[21] Mulugeta Eshetu, Shure Sebboka and Falmata Gezachew. 2017. Assessment, Resources Characterization and Mapping of Ilasa Watershed in the Case of Goba Distinct in Highland of Bale Zone, Southeastern Ethiopia. *American-Eurasian J. Agric. & Environ. Sci*., 17(6): 499-513.

[22] Thomas, D. B. (eds) 1997. Soil and Water Conservation Manual for Kenya. Soil and Water Conservation Branch. Ministry of Agriculture, Livestock Development and Marketing. 210 p.

[23] Zhao, Y., Jia, R. L. and Wang, J., 2019. Towards stopping land degradation in drylands: Water−saving techniques for cultivating biocrusts in situ. *Land Degradation* and *Development*, *30*(18), 2336-2346.