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Original Research Article

Watershed-Based Participatory Sustainable Land Management using Integrated physical SWC Measure in Ilasa Watershed of Goba District, Bale Highland South-Eastern Ethiopia

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Abstract: Soil erosion is among the most challenging and continuous environmental problems in the highlands of Bale particularly in Ilasa Watershed of Goba District. Soil erosion which emanates from both anthropogenic and natural causes currently results decline in agricultural productivity, crop production on the other hand increases downstream flooding and reservoir sedimentation, and loss of valuable plant nutrients. Soil and water conservation (SWC) practices have been carried out to solve land degradation and erosion severity problems in the Ilasa Watershed through participatory approaches the objective of this study was to implement integrated physical SWC practices through participatory approach in the Ilasa watersheds; to rehabilitate degraded watershed using different physical SWC measures and to minimize the risk of soil erosion and increasing soil depth by trapping sediment loss from Ilasa watershed. Hence, different participatory integrated watershed management practices were introduced in the Ilasa watershed for five consecutive years to avert the problem of soil erosion. Community participatory in integrated watershed management particularly soil and water conservation measures interventions for degraded rehabilitation and gulley treatment were capacitated through training, practical field works, and researchable materials support. Awareness creation, increasing knowledge and skill of farmers, providing technical and resource supports, and implementing slope based appropriate SWC structure could help sustainable land management that ensures environmental quality and food security in the study area as well as in the other areas having related biophysical and socioeconomic settings. Among the major types of physical SWC structures and gulley rehabilitation structures constructed in the study watershed were soil bund; stone bund; stone-faced soil bund and cut-off drains, gully reshaping and filling, brushwood check dam, loose stone check dame, sandbag check dam were the common ones. These constructed SWC structures during intervention were supported by vetiver and desho grass using as biological SWC measures. It can be concluded that participatory integrated watershed management intervention brought a significant reduction in soil erosion and thereby improvement of rehabilitation. It should be recommended that periodic maintenance, further supporting with biological conservation measures, and promote such practices or intervention to similar watershed is needed. Further study on alternative watershed management practices or technologies from different perspectives is advisable to sustainably satisfy the benefits of the community and the viability of natural resources.

Keywords: Degraded land rehabilitation, soil erosion, soil, and water conservation.

INTRODUCTION

Soil erosion by water threatens the food security and environmental protection of the globe (Lieskovsky and Kenderessy, 2014). The watershed attributes extreme soil erosion, high runoff, and the highest rainfall intensity (Belayneh *et al.*, 2019; Fazzini *et al.*, 2015). Different researches were completed to quantify the rate of soil erosion in the watershed. Soil degradation due to water erosion is one of the serious constraints for agricultural development particularly in the highlands of East Africa (Karamage *et al.*, 2017; FAO, 2019). In Ethiopia, about 2 billion tons of soil, 50% of which is from cultivated land, is lost by erosion every year (FAO, 2019). According to Haregeweyn *et al.*, (2015) and Borrelli *et al.*, (2017) reported that on average, the

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combined erosion forms (sheet, rill, and gully) remove 30 tons of soil $ha^{-1}yr^{-1}$(which exceeds the recommended tolerable rate (10 tons of soil $ha^{-1}yr^{-1}$). Surface runoff (sheet and rill erosions) is a dominant forms of soil erosion by water, but less visible (Heri-Kazi and Bielders, 2021).

Soil erosion has different types, forms, and severity levels that cause land degradation and loss of crop production in a given watershed. Soil erosion in the form of rill; sheet and gully is among the hazardous forms of erosion cause loss of thousands of hectares of cultivated lands abandoned in the country (Belayneh *et al*., 2020). Mitigating soil erosion through proper soil and water conservation (SWC) measures should be a priority to ensure sustainable land uses, particularly on sloping lands subjected to cultivation. In Ethiopia, different SWC measures have been implemented in different parts of the centuries (Mukai *et al*., 2021). A study conducted by Belayneh *et al.*, (2019) and Zimale *et al*., (2017), reported that an average soil loss rate of 42 and 49.2 t ha^{-1} yr^{-1} respectively. Wubie and Assen (2019) showed the soil degradation index in the watershed was in the range of -236 to -364%, indicating that the area is subjected to high soil erosion. To reverse this trend, the Ethiopian government with the help of non-governmental organizations started a large-scale watershed development program to increase agricultural productivity, and reduce soil erosion. The program focused on the construction of the physical structure in the highlands for the last two decades.

Integrated watershed management is a method of continuous restoration, growth, and efficient use of available natural resources in a watershed, and a multidisciplinary approach to soil depletion pause (Mekonen and Fekadu, 2015). Studies showed that the implemented integrated watershed interventions increased infiltration and decreased runoff production (Taye *et al*., 2013); improved soil fertility (Nyssen *et al*., 2007) and improved vegetation regeneration (Mekuria *et al*., 2007); improved soil fertility (Nyssen *et al*., 2007); improved vegetation regeneration and soil build-ups (Etsay *et al*., 2019); improved groundwater (Nyssen *et al*., 2010). Investments in soil and water conservation (SWC) practices enhance crop production, food security and household income (Adgo *et al*., 2013). Recognizing these connections, this study was initiated with the objective- of implementing integrated physical SWC practices through a participatory approach in the Ilasa watersheds; rehabilitating degraded watershed using different physical SWC measures; to minimize the risk of soil erosion and increasing soil depth by trapping sediment loss from Ilasa watershed.

MATERIAL AND METHODS

Description of the study area

The study was conducted at Goba Districts in the Ilasa watershed which is situated 25 km away from Goba town of Bale zone of Southeastern Ethiopia where soil erosion; gully formation and loss of agricultural land are a serious problem for production and productivity in this area. Ilasa Watershed is located between in northern or the lower part of the watershed bounded by Walti Magida kebele on the southern or upper part of the watershed bounded by Barbare district, on the western part of the watershed which is bounded by Walti Qubsa kebele and in the eastern part of watershed bounded by who Misirge Kebele. Geographically, the study district is located at 6°57′30″ to 7°0′30″ North and 40°3′ 30″ to 40°6′0″ East and covering the total area of 506 ha having an elevation range from 2462 to 2991 amsl (Figure 1).

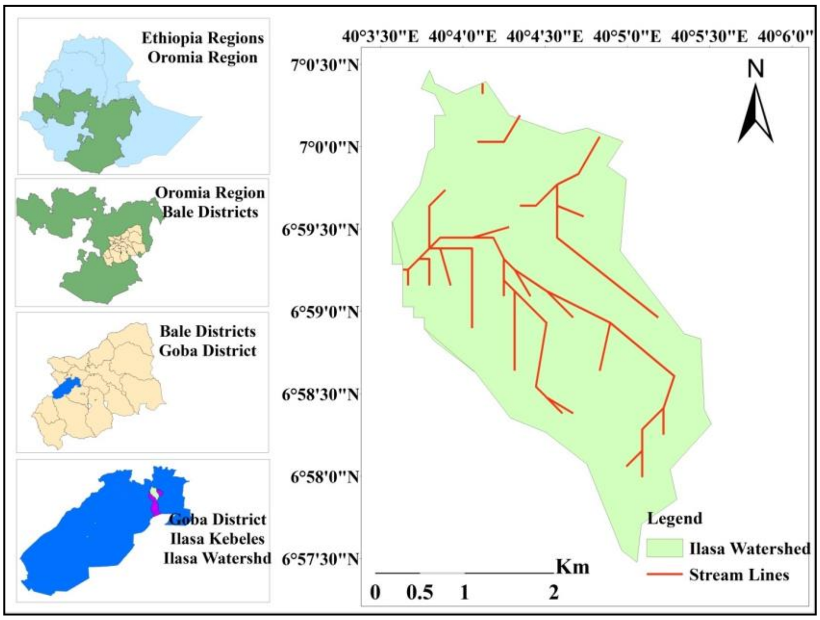

Figure 1: Map of the study site

Topography and Slope Characteristics of Ilasa Watershed

The effects of topography on land degradation depend on the effects of slope steepens and slope length. The ground's flat slope is important when considering the overall transportation of soil particles. The size and shape of the drainage area and generally its slope major affect runoff rate and velocity (Mulugeta *et al*., 2017). The slope classification based on recommendations for SWC structure implantation and layout given by Lakew *et al.*, (2005) categorized into five (5) classes namely; flat or almost flat (0 – 3 %), gently sloping (3 – 8%), sloping (8 – 15%), moderately steep (15 – 30 %) and steep (30 – 50%) as indicated figure 2.

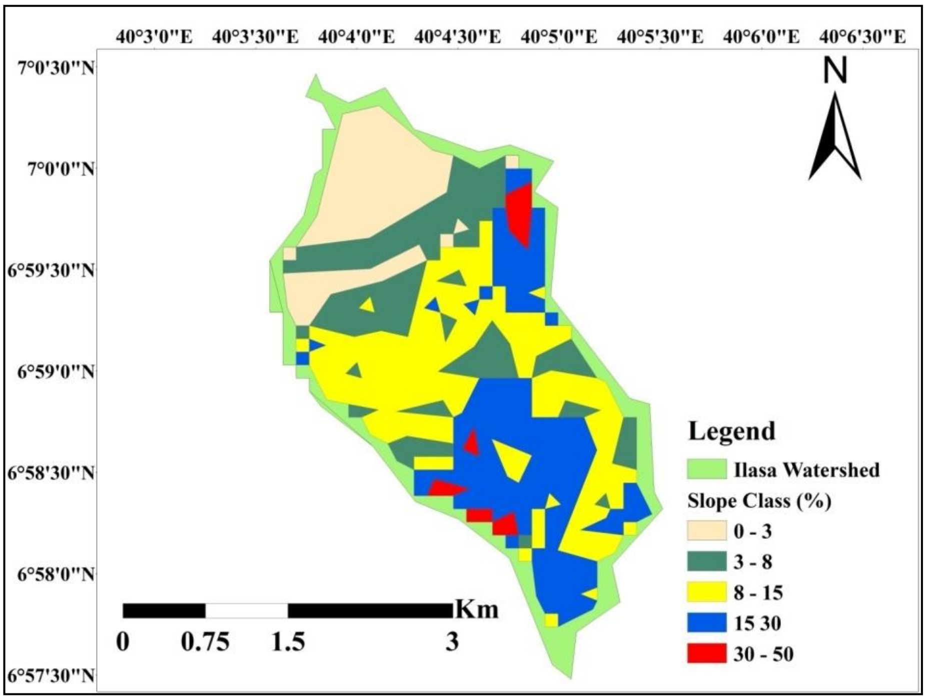

Figure 2: Slope Classes of Ilasa Watershed

Climate

As a part of the Bale zone, the Ilasa watershed of Goba District has two types of rainfall seasons. The long rainy season extends from March to April with high rainfall during June, July, and August.

The second rainy season of -the rainfall regime is influenced by equatorial westerly and easterly winds with rainfall during spring and autumn. Accordingly; the average monthly climate characterizes the watershed 22.64ºC; 8.58ºC and 195.69 mm; maximum temperature; minimum temperature and rainfall; respectively.

Soil and Vegetation

The major soil types are Chromic, PellicVertisols, and Luvisols. Vegetation coverage great contribution to interception rainfall, keeping sediment loss and managing interception rainfall, keeping sediment loss, and manage soil fertility. *Juniperus procera, Eucalyptus, Olea europace, HageniaAbyssnica, cordial africana, suppresses* and other shrub as well as bush encouragement are grown in the area. However most of the indigenous tree exposed to deforestation for firewood, construction, and agricultural expansion (Mulugeta *et al*., 2017).

Community Participation; Approach and Activities Innervations

The local communities' involvement in watershed management activities through mobilizing through awareness creation; training; labor payment in the form of incentive; FRG and watershed use associations organizing, materials used for SWC measures such as wood and gabion providing which support critical to program success.

Layout and Construction of SWC Structures as Interventions

In these works, Lakew *et al.,* (2005) and the Ministry of Agriculture (2016) guidelines were adopted in addition to considering slope and soil types. Generally; some constructed soil and water conservation structures in the Ilasa watershed were described as follows. In addition, the standard for SWC measures convenient for Ox-ploughing was considered during intervention practices in the Ilasa watershed.

***Level soil bund*:** was constructed for slopes above 3 - 15% gradient. Based on this the design, layout, and minimum technical standards for construction-level soil bund were considered during construction. Accordingly; Height: min. 60 cm after compaction; Base width for stable soil: 1-1.2 m and (1 horizontal: 2 verticals), Base width for unstable soil: 1.2-1.5m in unstable soils (1 horizontal:1 vertical), Top width: 30 cm (stable soil) - 50 cm (unstable soil); Length of bund: 30-60 m in most cases, higher (max 80m) on slopes 3-5% and need to be spaced staggered for animals to cross and Vertical intervals*:* = 1-1.5 m for slope ranges 3-8%, vertical interval = 1-2 m for slope ranges 8-15% and vertical intervals = 1.5-2.5 m for slope ranges 15-20%, generally follows a flexible and quality oriented approach.

***Stone-faced soil bund*:** The design, Layout and Minimum technical standards for constructions stone-faced soil bund were grade of the lower stone face: 1 horizontal: 3 vertical; lower stone face riser foundation: 0.3 depth x 0.2 - 0.3 width; upper stone face riser foundation: 0.2 x 0.2 m; stone size: 20 cm x 20 cm stones (small and round shape stones not suitable); top width: 0.4- 0.5 m; height: min. 0.7 and max. 1 m; ties required: at every 3-6 m along channel; sink hole: is required at every 6-8 m; vertical interval: 1-1,5 m for slope 3-8%, 1-2 m for slope 8-15%, 1.5 - 2.5 m for slope 15-30% while for slope above 30% only in very stable soils or shift to stone bunds.

***Cut-off Drain*:** were constructed following the SWC measures minimum standard such as gradient: 0, 5 –1% max without scour checks. From 1 to 2% with scour checks; shape: Parabolic or trapezoidal; embankment: minimum 0,5 m top width, all slopes cut to grade of 1 to 1; scour checks (for gradients 1 – 2%).

***Stone Check-dam*:** was constructed follows the SWC measures minimum standard 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.

RESULTS AND DISCUSSIONS

Awareness Creation and Capacity Building

There are several factors that affect the farmers' participation in sustainable integrated watershed management technologies so to ensure successful implementation of these technologies, it is essential to ensure people's participation. Keeping this in view, before introduction of new integrated watershed management technologies and on layout, technical and design of SWC structures training have a curtail role for successful innervations. Awareness creation, strength capacity building; improving community participation great role in sustainable integrated watershed management for rural communities on integrating crops, livestock, and natural resource management technologies, particularly for the Ilasa watershed of Goba district in area of severe soil erosion and land degradation problems (Mulugeta *et al*., 2017).

The study gives more attention to training and discussion with different stakeholders on the practical and technical training as well as experience sharing of model practices to ensure participatory sustainable natural resource management at the Ilasa watershed. Based on this, a total of, 473 participants were involved in the watershed management capacity building program among these 306 and 167 were male and female households; respectively (Table 1). This approach created positive efforts among farmers in which perceived benefits of SWC measures as socioeconomic pillars, motivated farmers to participate in watershed management, skill enhancement of households, and encourage women's roles and linkages in these intervention works.

Table 1: Training on awareness creation and capacity building at Ilasa watershed

Years	Experts				DAs				Farmers		Total
	M	**F**	**Total**		**M**	**F**	**Total**		**M**	**F**	
2018	3	1	4		2	-	2		30	17	47
2019	4	1	5		4	-	4		140	60	200
2020	2	1	3		2	-	2		30	10	40
2021	1	-	1		3	-	3		50	50	100
2022	3	1	4		2	-	2		30	26	56
Subtotal	**13**	**4**	**17**		**13**	**0**	**13**		**280**	**163**	**443**

Participatory Implemented Physical SWC Measures and Gulley Rehabilitation Structures

Soil erosion is one of the biggest bottlenecks to agricultural productivity, crop production, and community livelihood of the Ilasa watershed (Figure 2). The baseline survey shows that the watershed had steep slopes, high rainfall, and improper cultivations therefore; to reduce these problems integration of physical and biological soil and water conservation measures is very important.

Participatory implementation of degraded land rehabilitation through the construction of integrated physical and biological soil and water conservation measure such as -cutoff drains, stone bunds, soil bunds, grass waterway planting of multipurpose trees recommended for Ilasa watershed (Mulugeta *et al*., 2017). Keeping this in view, different soil and water conservation measures (SWC) have been carried conducted in the Ilasa watershed of Goba District from 2018 to 2022 for five (5) consecutive years. The most common physical soil and water conservation measures practiced were soil bund; stone bund; stone faced soil bund and cut-off drains as indicated (Figure 3). Similarly; Dimtsu (2018) also reported such physically integrated watershed management structures in Maego watershed of northern Ethiopia.

Gully formation and expansion is the major problems that causes agricultural land loose, damages different resources in the area (Figure 3). Participatory gully rehabilitation, treatments and reclamation for sustainable watershed management through gully reshaping and filling, brushwood check dam, loose stone check dame, gabion check dam, sand bag check dam and gully bed and sidewalls plantation with water loving or moist tolerant tree, shrub and grass (Mulugeta *et al*., 2017). Based on these recommendation gully rehabilitation structures such as stone check dam; wood check dam; sediment storage dam; gully reshaping and planting; live check dam; sand and soil filled check dam; cut-off drains were used were implemented in Ilasa watershed.

Figure 3: Status of land degradation and gulley severity at Ilasa watershed before intervention

Figure 4: Picture during community-based participation in implementing soil and water conservation structures in Ilasa watershed

Biological SWC measures Implemented and distributed at Ilasa Watershed

Applying multipurpose grass as an integrating with physical structure contributes incredible benefits in reversing degraded land via soil and water conservation practice and for sustainability of implemented physical SWC structures. Among them vetiver and Desho grass is the best biological method, which effectively curtails in reducing soil erosion problems. In order to reverse the problems of soil erosion, the adoption of soil and water conservation (SWC) practices which are economically feasible, environmentally sound and replicable is paramount importance for sustainable production of Agricultural crops among this vetiver grass particularly for Bale highland (Mulugeta *et al*., 2017). Based on this recommendation the two common multipurpose grass species vetiver and desho grass distributed in order to farmers establish Nurseries at community and watershed level, as well as also plantation on private and communal lands these two compatible multipurpose grass species were distributed for Ilasa watershed of Goba district (Table 2).

Table 2: Vetiver and Desho grass distributed for Ilasa watershed managements

Years	Number of Stocks	Numbers of Splits
	Desho grass distributed	
2020	288	10,791
2021	219	8,937
2022	263	12,475
Total	**770**	**32203**
	Vetiver grass distributed	
2020	300	12,000
2021	500	15,000
2022	800	10,000
Total	**1600**	**37,000**

Figure 5: Planting of biological SWC measures as support of physical SWC structures

Contribution of Intervention Implemented at Ilasa watershed

Following the assessment, resources characterization and mapping of Ilasa watershed of Goba distinct of Bale Highland different SWC structures both physical and biological SWC measures implemented as intervention by Sinana Agricultural Research Center; Soil fertility Improvement and Soil and Water Conservation; Watershed Management Research Team. Consequently, positive impacts were achieved as compared to before intervention. The immediate outcomes of integrated watershed management interventions in Ilasa watershed include rehabilitation of degraded land; reduction in soil erosion and associated downstream siltation; and regeneration of plant resources (Figure 6). The above success of soil and water conservation measures implemented for rehabilitating degraded land following participatory integrated watershed management approach at Ilasa watershed is one of the major indicators for the benefits to local households, farmers, the local community, and the society at large.

Figure 6: Ilasa watershed status after intervention

CONCLUSION AND RECOMMENDATIONS

Community participation was developed through given training and experience sharing to develop awareness creation for the local community and capacity building about layout of structures for the local technical leaders should be given. It can be concluded training and awareness creation prior and great role before intervention to ensure effective participatory sustainable integrated watershed management practices at Ilasa watershed.

Hence, different integrated watershed management practices were introduced in Ilasa watershed for five consecutive years to reduce the problems of land degradation as results of high soil erosion. Among the major types physical SWC structures and gully rehabilitation structures constructed in the study watershed were soil bund; stone bund; stone faced soil bund and cut-off drains, gully reshaping and filling, brushwood check dam, loose stone check dame, sand bag check dam were the common ones. These constructed SWC structures during intervention were supported by vetiver and desho grass using as biological SWC measures. During theses participatory SWC layout, construction and intervention most of the structures, meet the site-specific vertical intervals/slope, width and height standards. The type and quantity of these measures vary by variation in slope, runoff volume and intensity of land degradations. The watershed management intervention in Ilasa watershed of Goba District was effective in several aspects. The findings indicated that the watershed management intervention brought reduction in soil erosion and thereby improvement of rehabilitation.

It should be recommended that periodic maintenance, further supporting with biological conservation measures and promote such practices or intervention to similar watershed needed. Hence, integration among the community, government and non-governmental organizations are needed to for further sustainable management of natural resource resources in Ilasa watershed. Further study on alternative watershed management practices or technologies from different perspectives is advisable to sustainably satisfy the benefits of the community and viability of natural resources.

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