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Research Article

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Assessment and Documentation of Indigenous and Introduced Soil and Water Conservation Measures in Some Parts of Southern Ethiopia

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Abstract

In Ethiopia, soil and water conservation (SWC) activities were initiated after the famines of 1973 and 1985. Subsequently, various conservation measures were implemented by the government and non-governmental organizations to improve sustainable agricultural production. This study was designed to identify, measure, and describe indigenous and introduced soil and water conservation practices in four zones of Southern Ethiopia, namely Wolaita, Hadiya, Kambata Tambaro, and Dawro. It was found that biological, physical, and agronomic measures were implemented in the study area. However, the technical evaluation results reveal that certain practices, such as traditional cutoff drain, fanya juu, soil bund, stone-faced soil bund, brushwood, and gabion check-dams face technical, social, and institutional challenges. The results also indicate that less attention has been given to indigenous SWC practices by different stakeholders including government organizations (GOs), non-governmental organizations (NGOs), and research institutes. As a result, their respective dimensions were not modified, effective measures were not upscaled, and circulated to other areas with similar agroecology and farming systems. In general, farmers in the study area are well acquainted with soil erosion, its causes, and the consequent reduction in land productivity. The results of our research will undoubtedly aid in identifying and documenting the practices that have been identified for future reference.

Keywords: Agricultural Production, Agro-Ecology, Climate Change, Effective Measures, Food Security, Soil Erosion

1. Introduction

In Ethiopia, soil and water conservation (SWC) activities were started after the famines of 1973 and 1985 with different programs launched by the government and non-government organizations (GOs and NGOs) from which the food-for-work program was implemented for a long time [1]. Following this program, different physical and biological soil and water conservation measures were implemented by community campaign and house hold level. Similarly, various land productivity enhancing technologies and practices have been introduced by research institutions, extensions, and other development practitioners in the region [2]. In contrary, farmers from their experience implemented various indigenous SWC measures.

Indigenous soil and water conservation is the method used by farmers to enhance the optimum level of production from a given area of land while keeping the soil loss below critical level. The soil loss tolerance value is defined as the rate of erosion at which soil fertility can be maintained over at least 25 years [3]. Indigenous soil and water conservation practices have very often been ignored or underestimated by development agents, researchers, soil conservationists, and government staff [4]. Although the objectives of knowing indigenous soil and water conservation practices give us an understanding of farmers' way of thinking about the measures [5]. Farmers use several indigenous SWC technologies to prevent the problem of soil erosion. Among these is cutoff drains, leaving crop residues in the field, distribution of manure, contour farming, fallowing, planting root crops by preparing bunds, tree planting on slope farm, use of trash lines on contour, row planting, alley cropping, intercropping, strip planting, and plantation of Sisal (Agave sisalana Perrine) and euphorbia (Euphorbia classenii) on the farm. According to, most of the farmers in south western Ethiopia practices introduced and indigenous SWC activities like; contour farming, furrow making, residue leaving, agronomic practices, and putting trash lines on contours [6]. Broadly the conservation measures are classified as agronomic measures, physical /structural measures, and biological/vegetative measures [4].

It should be emphasized that before introducing a new technology it is necessary to check whether local soil and water conservation measures already exist and why and how farmers apply these indigenous technologies. If such technologies exist and continue to be applied by farmers, then, providing they have not been introduced and maintained by legal force and state authority, they can be considered successful and, on the investigation, found to provide tangible benefits. Understanding the reasons why farmers use such technologies, i.e. the production and conservation benefits they get from them, is the key to the successful introduction of any “new” technology, which must at least match and preferably improve on the benefits to be obtained from the existing ones [7].

The effect of SWC measures in reducing soil loss generally varies with soil type, land use, land cover, topography, climate, and intensity of the measures. In this regard, the major factors like farming system and land use/land cover which are related to the daily activity of landowners/farmers/. Therefore, they protect their soil indigenously for their crop productivity. Different authors assessed many indigenous SWC practices that can reduce soil loss however it was not organized in a form of integrating its historical analysis, source and property, technical, social, economical, and cultural aspects. For this reason, this research was initiated to identify and investigate different indigenous and introduced SWC practices, to measure and describe identified SWC practices that could add value to reducing soil erosion and increasing moisture on farms so that, it would be documented for future development.

2. Methodology

The Southern Nations, Nationalities and Peoples’ Region (SNNPR) is one of the nine regional states of Ethiopia. Geographically it is situated between the coordinates of 40 27’ and 80 30’ N and 340 21’ and 390 11’ E with altitudes ranging from 376 to 4207 masl and with mean annual temperature ranging from 150 c to 300 c [8]. It covers approximately a total area of 110931.9 km2. It has a very diverse agro-ecology and classified as lowlands, mid, and highlands covering 57.4%, 34%, and 8.6% respectively. SNNPR has 13 major and 19 sub-agro-ecological zones [9]. The rainfall pattern of the region is bimodal with small rain in the dry season and high rainfall in the main rain season with mean annual rainfall ranging between 400 mm in the extreme south of Debub Omo zone and over 2200 mm in the west in Sheka and Kaffa zones. SNNPR has a total population of 15.04 million of which 89.72% of the people are living in rural areas and 10.28% are urban dwellers [10]. The population density ranges from 4 to 900 persons per square kilometer. The average landholding size of the region is estimated to be 0.75 ha which lies below the national average (1.2 ha) [11]. The region has typical ethnic-cultural diversity comprising more than 56 distinct nationalities living in different agro-ecology all having their own culture, farming system, and indigenous knowledge of managing natural resources.

The study was conducted in four Zones of Southern Ethiopia namely Wolaita, K/Tambaro (Kambata Tamabaro), Hadiya, and Dawro.

2.1 Sources of Data

Data for this study was obtained from primary and secondary data sources. Primary data was obtained from household (HH) survey, field observation, characterization of structures, focus group discussion (FGD), and key informant interview (KII). Besides, zonal and district agricultural experts, Kebele administrators, and Development agents (DAs) were used as primary data sources. On the other hand, secondary data was obtained from unpublished and published materials such as official records and project reports.

2.2 Sampling Procedures

It is a fact that, in different agro-ecological zones, different SWC practices have been implemented. As a result, representative sample districts and kebeles were purposely selected from different agro-ecological zone from some parts of southern Ethiopia. To select representative districts and kebeles, a detailed discussion was organized with zonal and district agricultural departments with a selected multi-disciplinary team composed of natural resources management, crop science, animal science, socio-economic, and irrigation who are well experienced and having detail information on farming system and SWC measures of the study area.

During the first stage, eight districts, two districts form each zone were purposely selected based on intensity and adoption of SWC practices. Similarly, during the next stage, three kebeles per district and twenty-eight kebeles in total were purposely chosen from respective agro-ecological zones, for the same reason. After all, for a detailed study, sample households from representative kebeles were purposely selected based willingness of the farmers to adopt the swc measures.

2.3 Method of Data Collection

The following data collection tools were employed to gather relevant information.

2.4 Field Observation

Field observation was undertaken to identify and verify acquired SWC practice during FGD, HH survey, and KII. Overall aspects of SWC practices were observed, measured, and described as well.

2.5 Formal Interviews

Formal interview was the widely used instrument for data collection with carefully constructed questions. Since, most farmers are local language users, enumerators were selected for formal interviews. Selected enumerators from each study site were fluent in speaking local languages and Amharic as well. Before the implementation of the survey, enumerators were trained and tested for their clarity and understanding of the questions. Then after, the survey was employed.

2.6 Focus Group discussion

During FGD two ways of communication were conducted between participants and interviewers to make the process of data collection more effective. In this way, participants could ask questions on problems of soil erosion and soil conservation. Selected questions from the same formal questionnaire and additional questions were also included that were supposed to be necessary to capture relevant information for focus group discussions. FGD comprises of 8 farmers from each kebeles (2, 2, 2, 2 elders, youth, female, and model HH respectively).

3. Result and Discussion

The results from the household survey, key informant interviews, field-level observation, and focus group discussion shows that, government organization, NGOs, and communities in separate and collaboration implementing three types of SWC conservation measures.

3.1 Biological Soil and Water Conservation Measures

The study revealed that farmers in the study areas implement three-folds of SWC measures. One is a biological conservation measure including area closure, grass strip, bund stabilizer, and live fence.

3.2 Area Closure

The study revealed that, to halt and rehabilitate land degradation, area closure as a biological conservation measure is exercised in Hadiya, K/Tambaro, Dawro, and Wolaita Zones. To facilitate regeneration of the vegetations, farmers integrate physical conservation measures in to area closure such as eyebrow basin, micro basin, gabion, brushwood and/or stone check dams, soil bund, stone-faced soil bund, stone bund, and trenches (Figure 1).

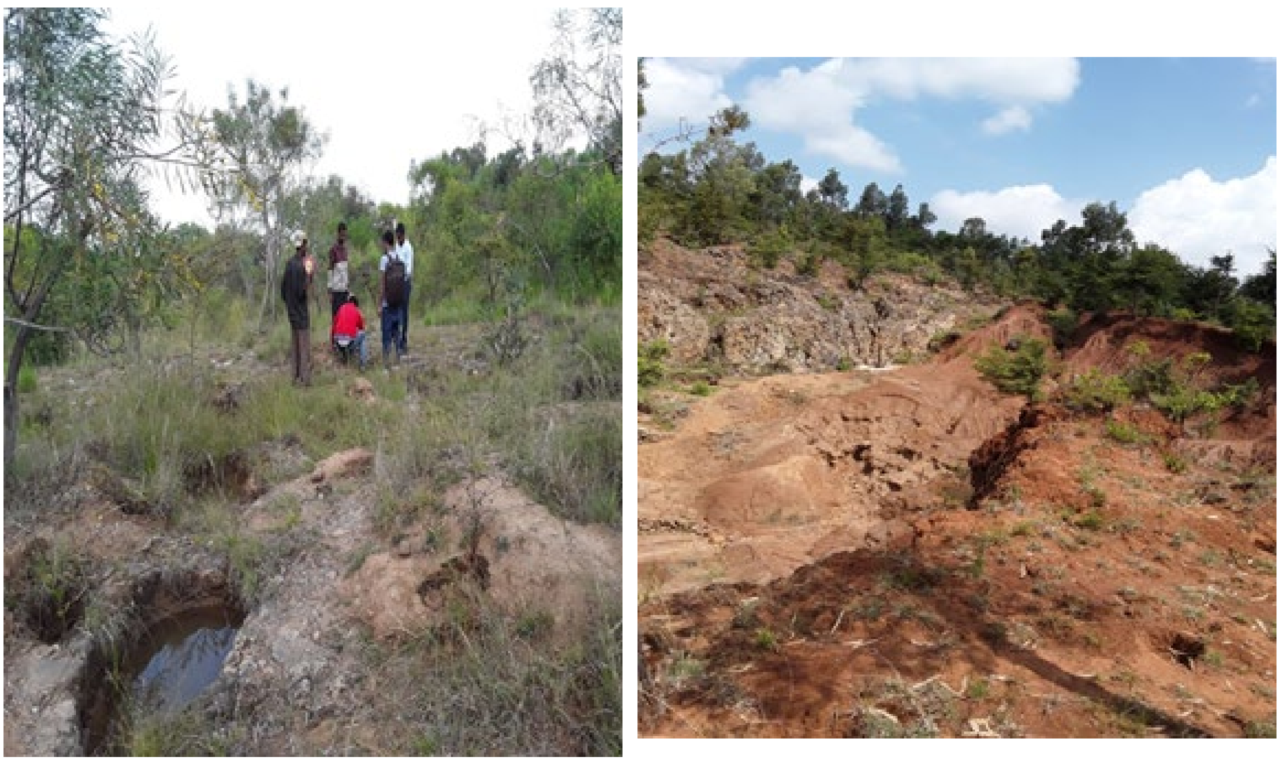

Figure 1: Area closure in a) K/Tambaro b) Hadiya (Source; field survey)

3.3 Grass Strip

This study shows that grass strip is not commonly practiced in the study area due to various reasons. The main detrimental factors were found to be free grazing and farmer's awareness gap. However, farmers who hosted grass strips pointed out that it is the least cost and less labor-consuming practice. The researchers investigated that the grass strip has the width ranging from 30 – 80 cm along the contour. Two types of grasses namely Desho and Elephant are commonly used as grass strip in the study areas (Figure 2).

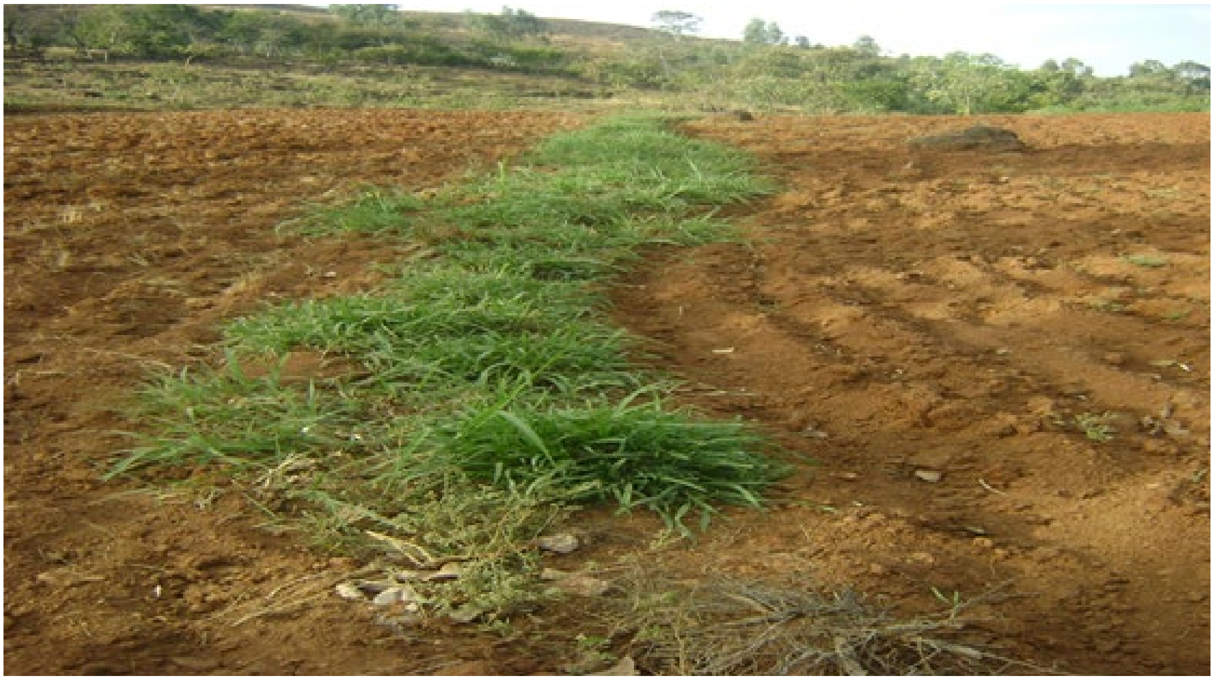

Figure 2: Shows grass strip at Wolaita (Source; field survey)

3.4 Bund Stabilizer

The result from group discussion, HH survey, KII, and transect walk revealed that farmers in the study area commonly practice different bund stabilizers. They integrate banana, desho grass, Elephant grass, and *Cajanus cajan* with constructed mechanical measures (Figure 3). Farmers stated that integrating biological measures has several benefits besides reducing and protecting runoff and soil erosion such as forage value, food value, income source, soil moisture improvement, and increased bund life span.

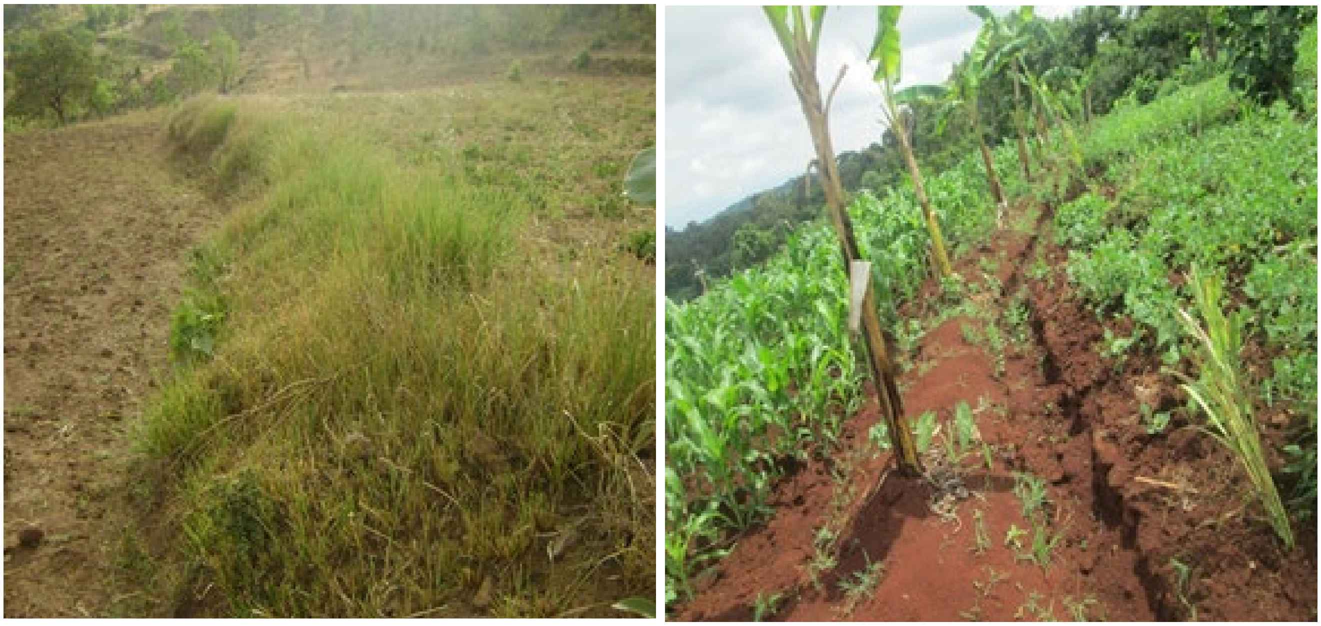

Figure 3: Bunds stabilized at a) Wolaita b) K/Tambaro (Source; field survey)

3.5 Live Fence

The study revealed that, traditionally, farmers plant various shrubs across the slope and around farm plots to reduce soil erosion and protect the crop from sudden damage by animals (Figure 4). This practice is very common in Woalita, Dawro, K/Tambaro, and Hadiya Zones of Southern Ethiopia.

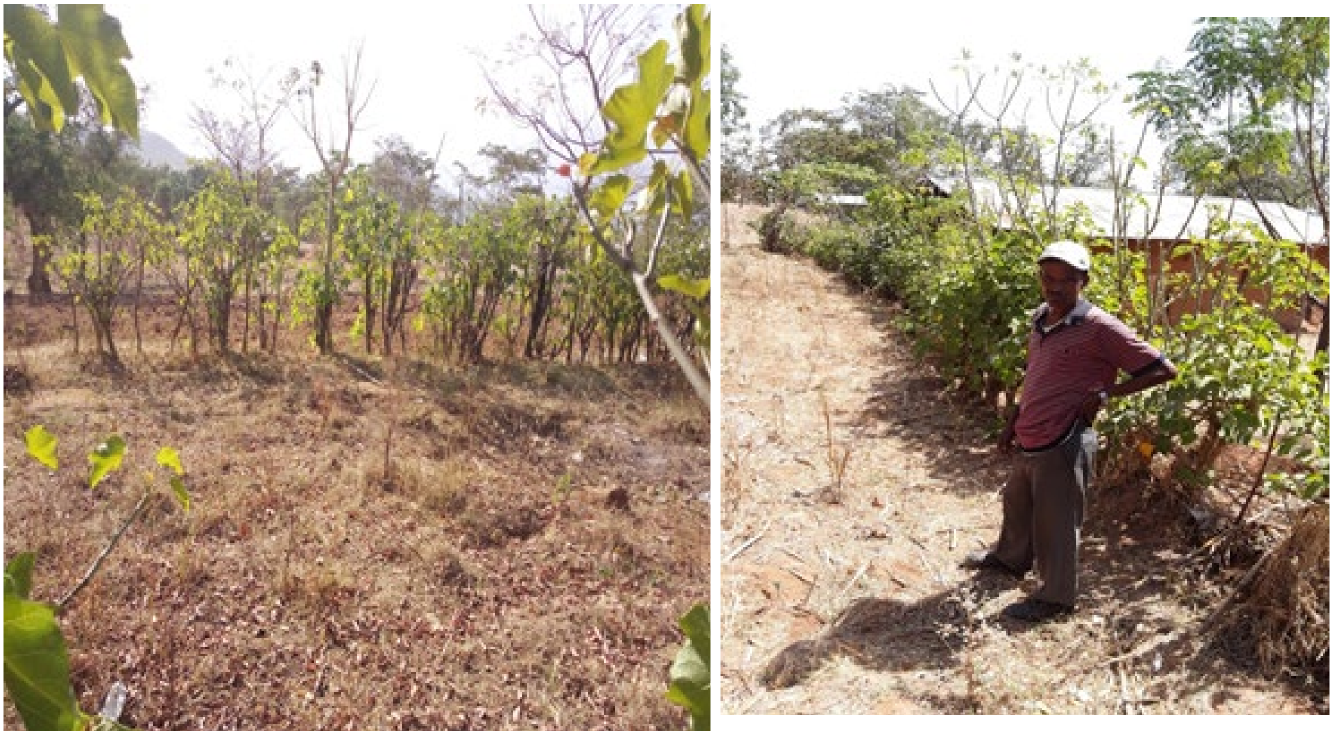

Figure 4: Live fencing at Dawro (Source; field survey)

4. Physical Conservation Measures

4.1 Soil Bund

A soil bund is an embankment constructed along the contour with a water collection channel at its upper side. It is constructed by throwing soil dug from the basin downslope (Figure 5). It aims to reduce runoff and erosion, increase infiltration, and reduce slope steepness. The result of this study shows that, the structures have short lifespan which might be attributed to free grazing, poor maintenance, and poor in plantation of stabilizers. During field measurement and characterization, the researcher obtained the following average dimensional result (Table 1). It has a tied ridge of 10 m intervals and a berm of about 15 cm from the embankment.

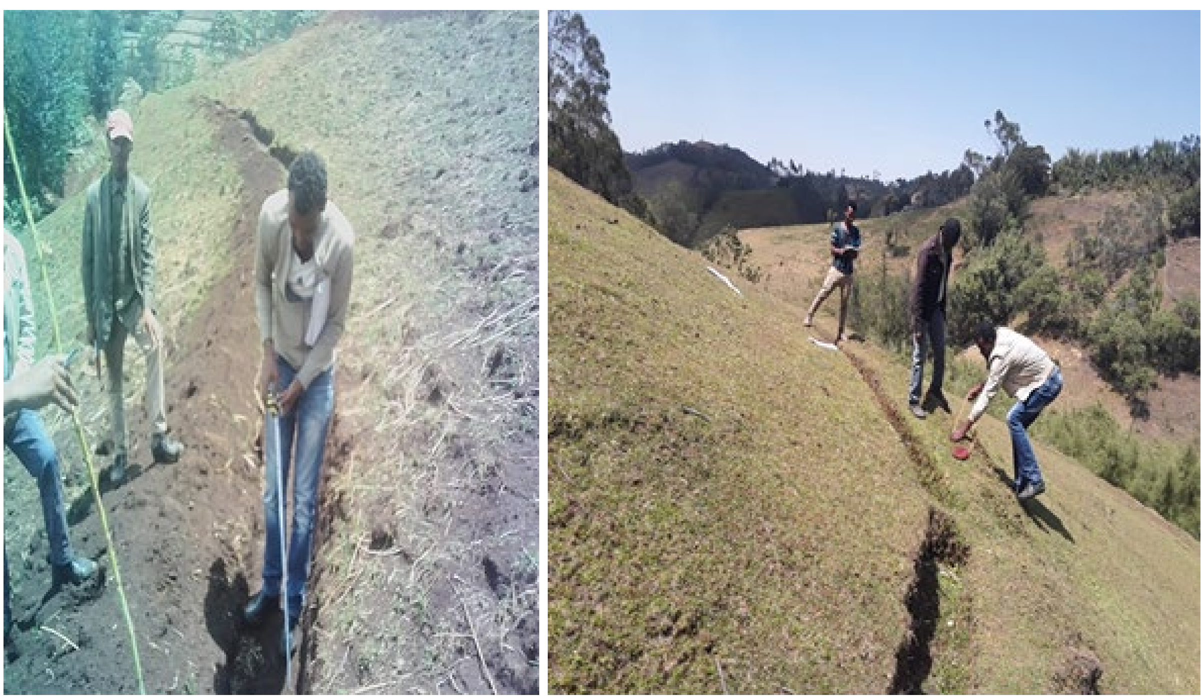

Figure 5: Field measurement on soil bund a) Hadiya b) Dawro Zones (Source; field survey)

Struc-ture name	Soil bund (cm)																			
Loca-tion	**Wolaita**					**Hadiya**					**K/Tambaro**					**Dawro**				
Di-men-sion	D	W	EH	EBW	ETW	D	W	EH	EBW	ETW	D	W	EH	EBW	ETW	D	W	EH	EBW	ETW
	45	30	40	70	32	42.1	60	33.6	94.3	40.4	50	50.3	42	86.3	31.25	36.4	44.3	21	81.7	25

Where: D; depth, W; width, EBW; embankment bottom width, ETW; embankment top width, and EH; embankment height.

Table 1: On field dimension of soil bund

4.2 Cutoff Drain

Farmers construct cutoff drain across the slope to intercept surface runoff and convey safe disposal from cropped land, roadsides, and homesteads to divert uncontrolled runoff to a safe out-late such as waterways, rivers, and preexisting gullies. Besides, sample respondents stated that, traditionally, farmers have resemblance to divert water from the crop land to boundaries. This in turn creates and exacerbates preexisting gullies, reduces the productive land size, and hinders the free movement of man and livestock from field to field. They construct it in a graded manner during planting and rainy times with a spacing of necessity. They also construct cutoff drains around roadsides and homesteads to divert uncontrolled runoff.

On croplands, they construct commonly using oxen and its dimension is nearly equivalent to the size of *"Mofer"* which is about 30 cm * 30 cm in depth and width. However, farmers with no oxen construct by hand using a fork, spade, and other digging materials. Locally it is named *"Boyea"* (Wolaita and Dawro). They believe that cutoff drain construction has two-fold advantages including production and conservation value. Besides, it is constructed to protect removal of inputs (seed and fertilizer) from crop land and prevent water from entering the house [12]. On the contrary, farmers implement diversion ditches based on standard guidelines developed by the Ethiopian Ministry of Agriculture (MoA). However, the difference observed is in technical standards between the structures.

4.3 Stone Bund

Stone bunds are used along contour lines to retard, filter and spread-out runoff water, thus increasing infiltration and reducing soil erosion. Through time sediment deposits, apprehend on the upper side of the bunds, form terraces. The farmers in the study area had practiced stone bund with advanced way mostly in stony area. This study revealed that stone bund structures were not well supported with biological stabilizers (Figure 6). Besides, its on-field technical status was evaluated and found to be deviated from the standard (Table 2).

Figure 6: Stone bund at Wolaita (source; filed survey)

Structure name	Soil bund (cm)																			
Location	Wolaita					Hadiya					K/Tambaro					Dawro				
Technical aspect	F	HB	TW	BW	F	HB	TW	BW	F	HB	TW	BW	F	HB	TW	BW	W	EH	EBW	ETW
	30	80	30	50	-	-	-	-	30	50	30	75	30	71.3	25.7	66.3	44.3	21	81.7	25

Where, Foundation of the bund (F); Height of bund (HB); Top width of bund (TW); and Bottom width of the bund (BW)

Table 2: shows the technical status of stone bund

4.4 Fanya Juu

This is an embankment constructed by throwing the soil dug from the basin to uphill and the term was coined from *Swahili* meaning throwing uphill [13]. The researcher investigated that farmer's in the study area do not exercise fanya juu as widely as other physical measures. The principal reason behind is its vulnerability to destruction and backfill of soil to the ditches. Its field dimension was measured and described in Table 3 as follows.

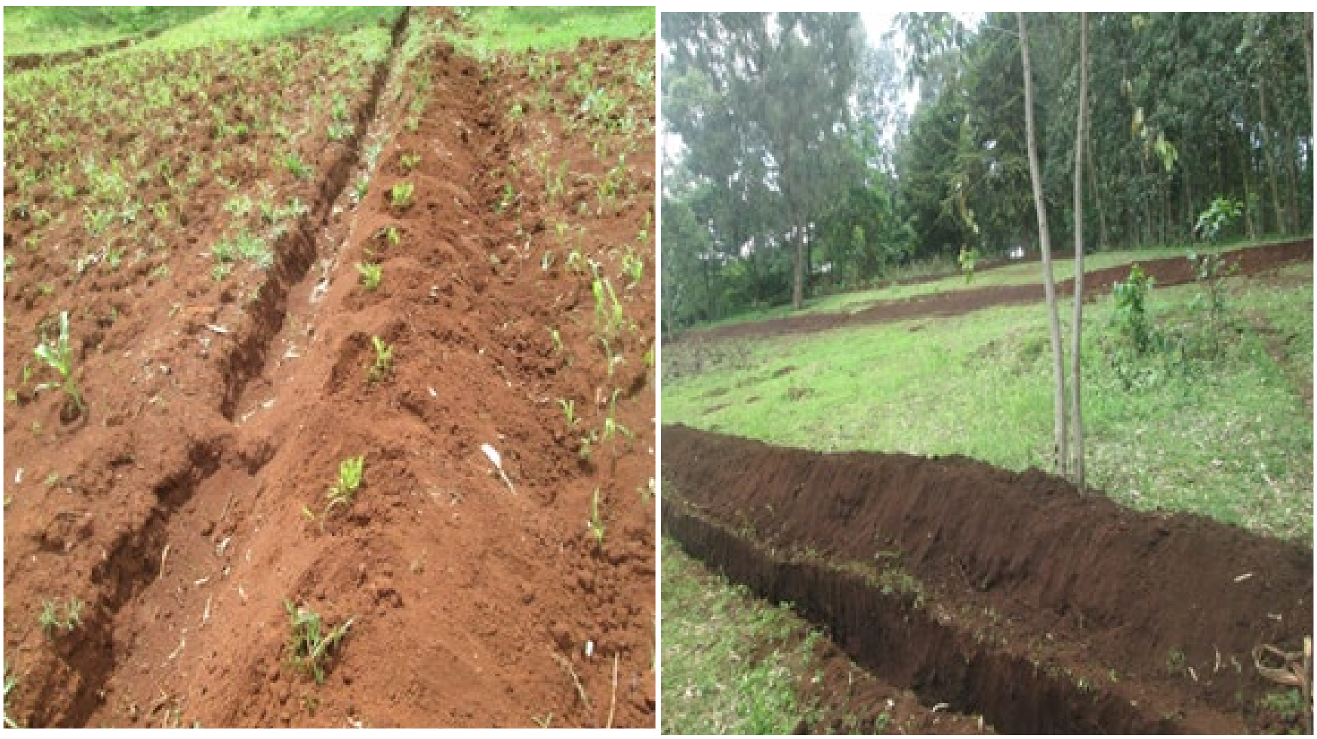

Figure 7: Fanya juu structure at K/Tamabaro (Source; field survey)

Structure name	Soil bund (cm)																			
Location	Wolaita					Hadiya					K/Tambaro					Dawro				
Dimension	D	W	EH	EBW	ETW	D	W	EH	EBW	ETW	D	W	EH	EBW	ETW	D	W	EH	EBW	ETW
	-	-	-	-	-	-	-	-	-	-	50	50	47.5	77.5	30	-	-	-	-	-

Where; Depth of the channel (D), Width of the channel (W), Embankment height (EH), Embankment bottom width (EBW), and Embankment top width (ETW).

Table 3: Dimensional characteristics of constructed fanya juu bund

4.5 Terrace (Bench and Hillside)

The study revealed that the community in the study area directly constructs a terrace on sloppy and mountainous land have enough manpower (Figure 8). The respondents dictated that in very steep slopes they maintain constructed soil bund, fanya juu, and stone bunds which gradually change into bench terraces.

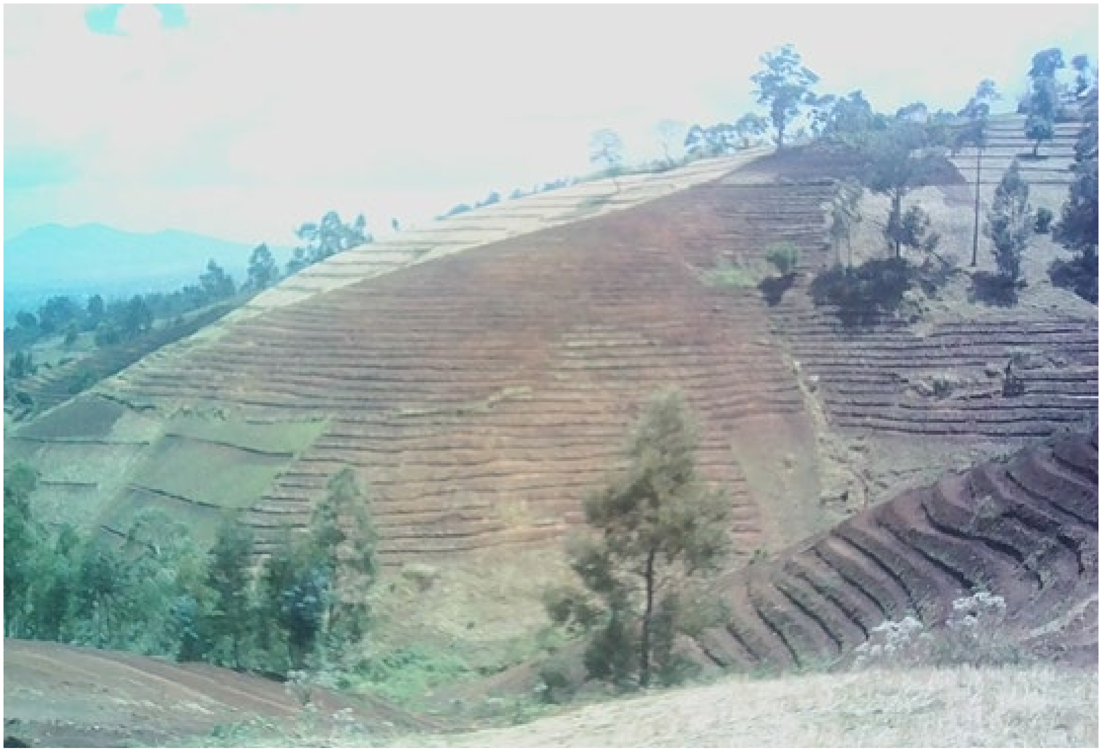

Figure 8: Hillside terrace at Hadiya (Source; field survey)

4.6 Stone Faced Soil Bund

Survey results revealed that, based on stone availability, farmers in the study areas commonly reinforce the lower bank of the bund with a stone riser on both on-farm and communal lands (Figure 9). The height of the riser depends on the stone in the area.

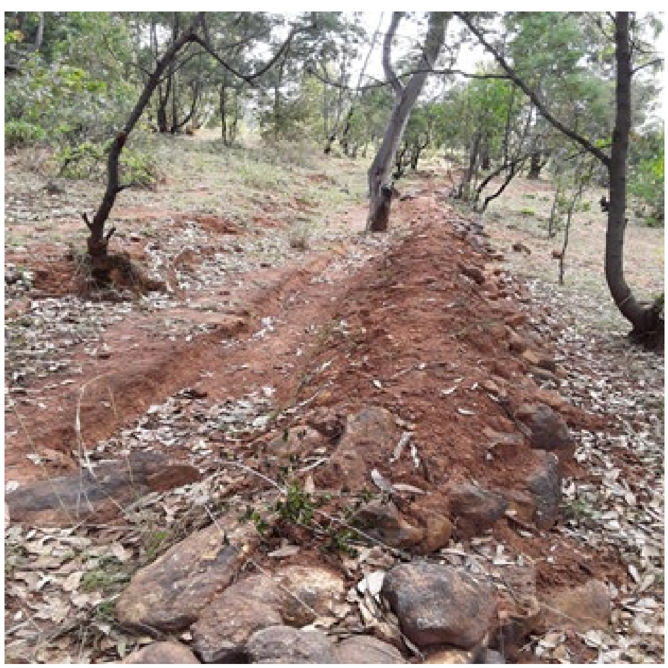

Figure 9: Stone-faced soil bund, Hadiya (Source; field survey)

4.7 Brushwood Check Dam

These are vegetative measures constructed from small wood branches and poles interwoven together. They are easy and cheap to construct using locally available materials. The result indicates that the structures are constructed in a small gullies less than 2 meters. In the study areas farmers commonly practice single row brushwood check-dam; although, it depends on the availability of local materials. However, the constructed check-dams have poor design and the material used are non-regenerative which are the major gaps observed (Figure 10). Besides, the poles used do not bit the required diameter, not straight enough, not integrated with multipurpose plant, and plant species used were not ideal. As a result, it becomes damaged and the gully is not well conserved.

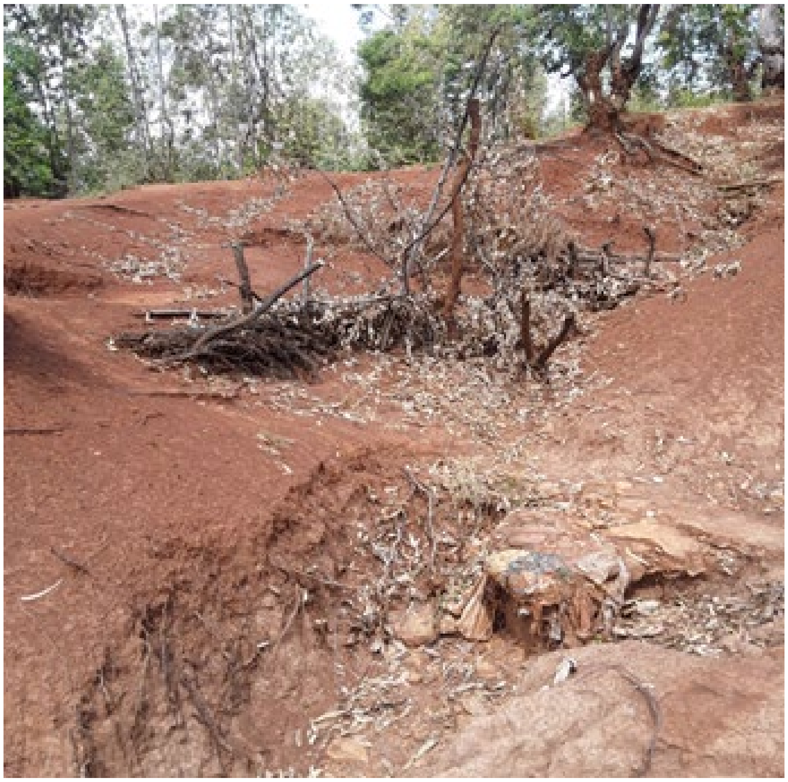

Figure 10: Brushwood check dam, Hadiya (Source; field survey)

4.8 Gabion Check-Dam

Gabions are rectangular boxes of varying sizes and are mostly made of galvanized steel wire woven into the mesh. Stabilization of gullies involves the use of appropriate structural and vegetative measures in the head, floor, and sides of the gully. The study revealed that the gabion check dam had been practiced to rehabilitate and prevent further expansion of gullies in different study areas (Figure 11). The gap observed in Hadiya case is that of constructed gabion check-dam lacks side key and spillway. As a result, side wall sliding of the gully is noted.

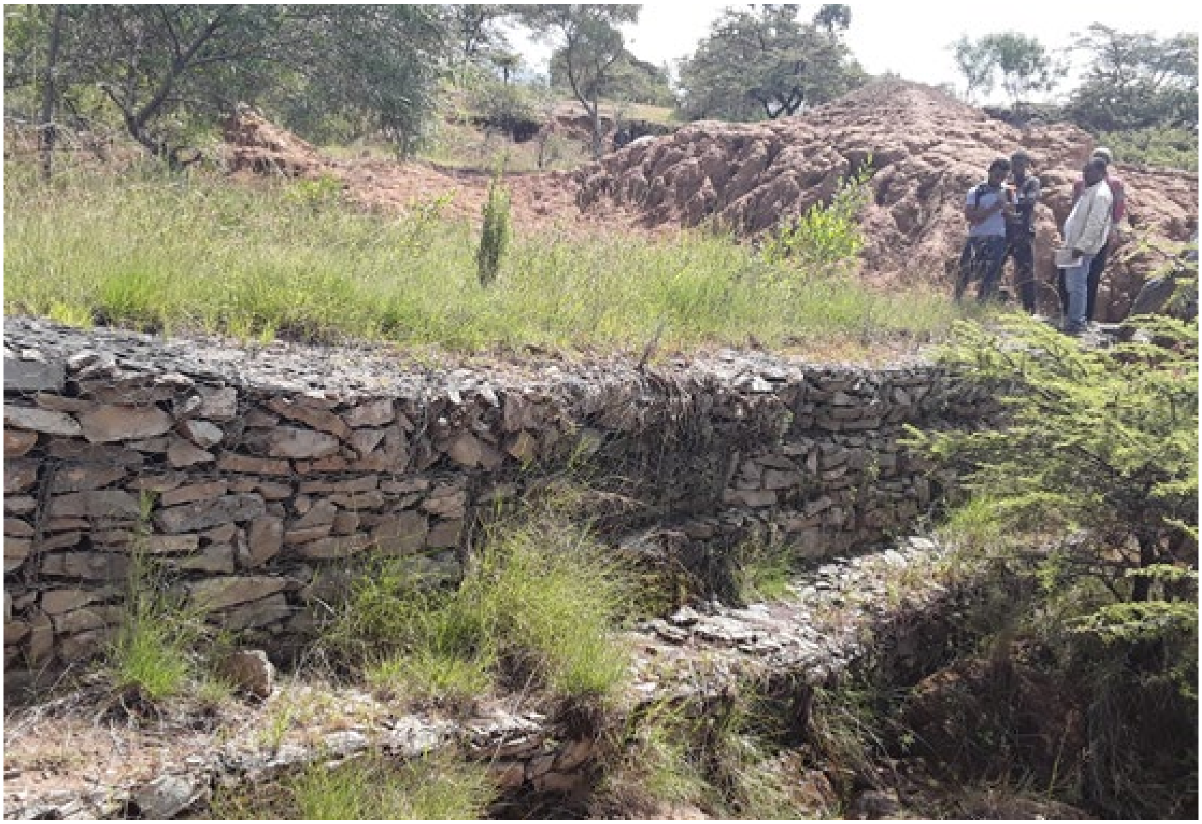

Figure 11: Gabion check-dam at K/Tambaro (Source; field survey)

4.9 Trench

Trenches are large and deep pits constructed along the contours with the main purpose of collecting and storing rainfall water to support the growth of trees, shrubs, crops, and grass or various combinations of those species in moisture-stressed areas [14]. In the study, area trenches were constructed in a staggered manner (Figure 12).

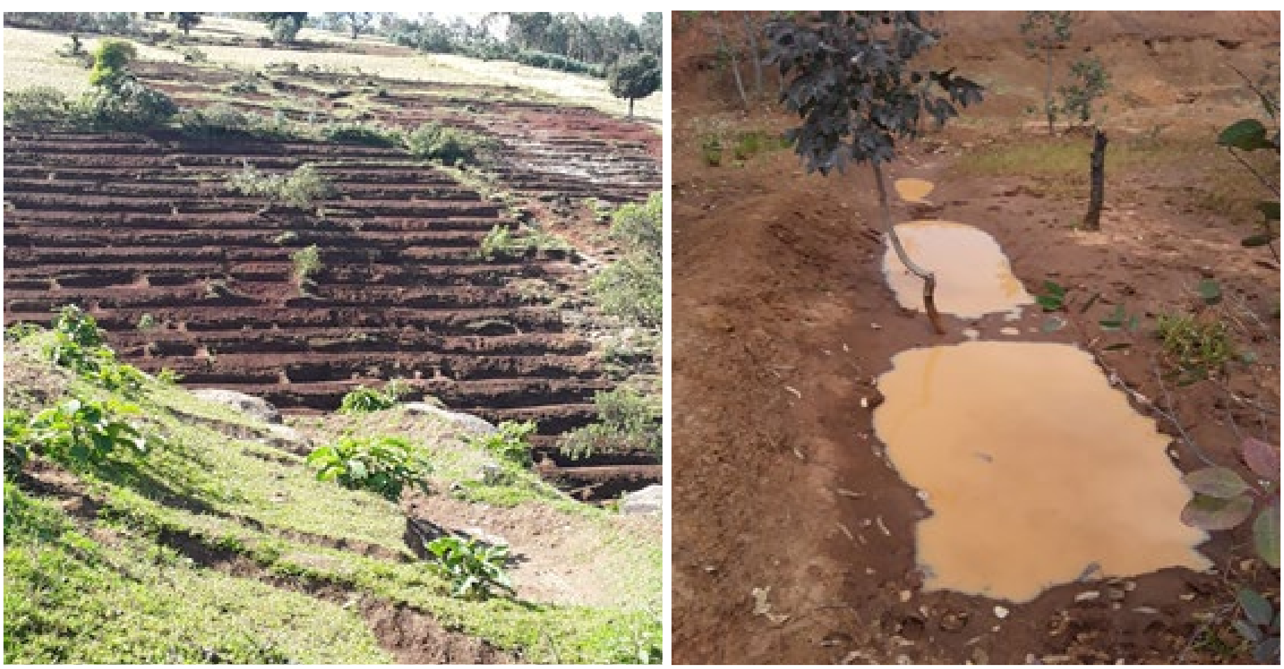

Figure 12: Shows trenches in Lemu woreda, Hadiya (Source; filed survey)

4.10 Micro Basin

Micro basins are small structures constructed by excavating half-circle basins mostly for plantation and in situ water harvesting. In the study areas, there is a practice of micro basins for tree plantation but the practice is very limited. The constructions of micro-basins in the study areas excavated soil in specific diameters to conserve water for plantation (Figure 13). The spacing between basins along the contour line is determined by plant spacing and the distance along the slope. Its onsite dimension was measured and presented in Table 4 below.

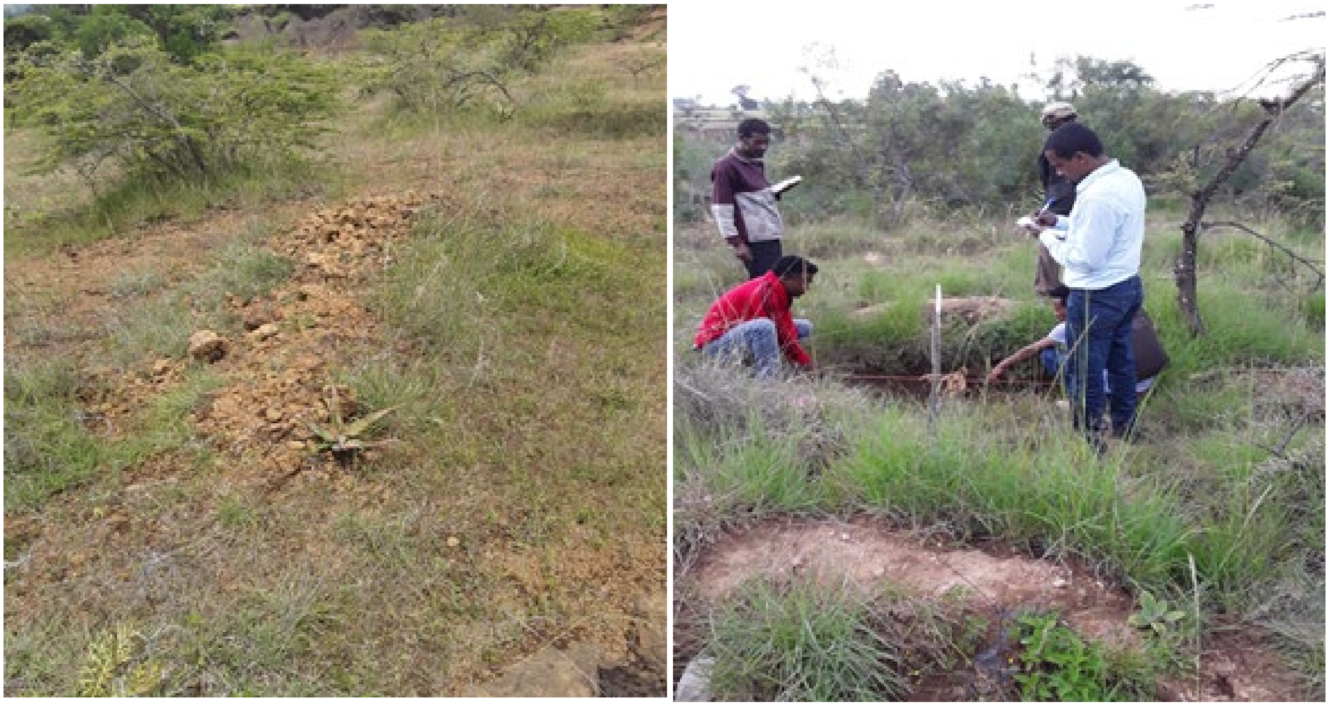

Figure 13: Shows Micro basin taken at Hadiya and K/Tambaro (Source; field survey)

Structure name	**Micro basin (cm)**																											
Location	**Wolaita**							**Hadiya**							**K/Tembaro**							**Dawro**						
Dimension	W	D	B	ETW	EBW	EH	DI	W	D	B	ETW	EBW	EH	DI	W	D	B	ETW	EBW	EH	DI	W	D	B	ETW	EBW	EH	DI
	-	-	-	-	-	-	-	120.3	61	27	19	48	26.7	390	-	40	10	40	78	43.4	208	-	-	-	-	-	-	-

Table 4: Dimensional characteristics of constructed micro-basin

4.11 Pond

The result from a sampled household, focus group discussion, and field observation revealed that farmers in the study area are excavating ponds as communal property. They use it as a water source for livestock and as an irrigation source for high-value vegetable crops. To control water seepage, they install plastic sheets as shown in the figure 14 below.

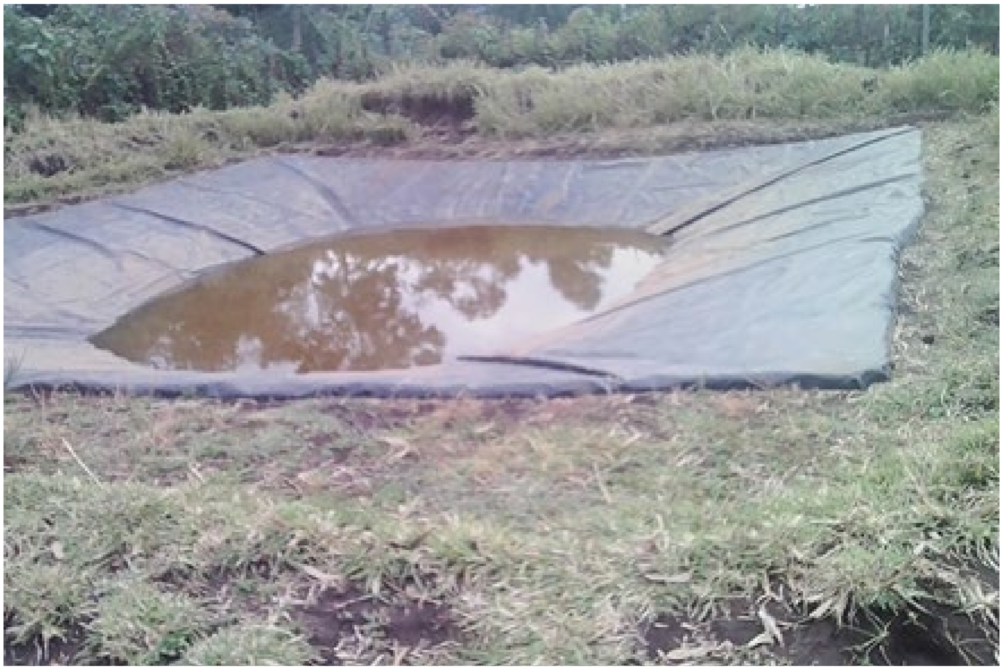

Figure 14: Communal pond, Hadiya (Source; field survey)

5. Agronomic Conservation Measures

5.1 Contour Furrow (*Shilshalo*)

In southern Ethiopia, harrowing (*shilshalo*) is common practice under the maize field to manage weeds. The study revealed that farmers in this area commonly practice Shilshalo not only to control weeds but also to harvest rainwater, enhance infiltration, and overcome moisture deficit for the crop during a dry spell.

Figure 15: Different sized yoke used for *Shilshalo* and plantation (source; field survey)

5.2 Mulching and Crop Residue Management

Traditionally, farmers in the study area uses crop residue as a mulch on their field (Figure 16). The sample respondents replied that mulching is the most conducive conservation measure since it is less expensive and demands less labor, and allows free oxen plow. In the study areas, materials commonly used for mulching are residue of Enset (at the home garden), banana, maize, and sorghum. Furthermore, they use the residue of common bean, wheat, and barley to reduce the susceptibility of the soil to erosion.

Figure 16: Mulching and crop residue management, Dawro (Source; field survey)

5.3 ContourFarming

Contour cultivation entirely practiced in study area. This study revealed that, farmers in the study area practice contour farming across the slope while implementing any farming operation. The sample respondents pointed out that contour farming is a good option to slow and impede downward water flow, increase rainwater retention and infiltration, and to avoid erosion. A study held by confirms that contour farming on a slope range from 4 to 6 percent can reduce water loss (runoff) by 50 percent and soil loss by about 50 percent compared to up and downhill cultivation [15].

5.4 Improved Fallowing

The study revealed that farmers use fallowing primarily as a means of reclaiming the productive potential of the soil. During FGD, farmers pointed out that, the fallow period and land size depend on the size and availability of land owned by households i.e., farmers with relatively large land size widely exercise fallowing. Whereas, farmers having limited land size exercise rarely and/or no fallowing.

6. Discussion

The efforts made in the last two decades, especially in the past few years to restore degraded land resources in-country Ethiopia were tremendous. Most of the measures implemented are physical conservation measures and had bring impact. But these alone do not directly influence biomass production [16]. As a result, nowadays, government organizations, NGOs, and communities in separate and collaboration are implementing integrated conservation measures. The study revealed that farmers in the study areas are implementing biological conservation measures. Its importance lies in the fact that these measures directly influence the biomass production and the protective plant cover on the land reduces soil loss and water at the same time it is used as food and fodder thereby enhances the survival and food security of the community. Similar study conducted by agrees with this finding [16].

The result indicated that due to high population density and land shortage, farmers cultivate steep and marginal lands to satisfy the increasing food demand of rapidly growing population. These factors significantly contributed to a high rate of land degradation. This finding shows that farmers in the study area integrate area closure with physical conservation measures to facilitate rehabilitation. The study conducted by reported that even if simple area closure without SWC can be an effective method for rehabilitating degraded hillsides, integrated SWC measures is the preferable way to speed up the rehabilitation period [17]. The grass strip was found to be one of the reasonable measures by reducing soil erosion. This is in line with study conducted by who reported the effect of appropriate vegetation measures on runoff and sediment reduction over time [18]. Farmers who hosted grass strips expressed their appreciation towards its role in minimizing soil erosion and runoff. They stated that it is used as fodder and source of economic. Though grass strips are least cost and labor-consuming measures, the effort made by farmers to implement grass strips was found to be below expectation due to free grazing and farmers' awareness gap.

In the study areas, farmers construct soil bund by community campaign beginning from February to December of the year. This finding indicated that GOs, NGOs, and associated organization supporting the establishment and strengthening of local institutions and farmers to exercise soil bund. Framers pointed out that level soil bund is widely and intensively used SWC measure in the study areas. It is aimed to reduce runoff, halt erosion, increase infiltration, and reduce slope steepness. This study agrees with the study held by [15,19].

The study revealed that in the study area farmers construct cutoff drains during planting and rainy season with a spacing of necessity to safely convey the runoff. On croplands, they construct commonly using oxen and the dimension is nearly equivalent to the size of a "Mofer" which is about 30 cm * 30 cm in depth and width. However, farmers with no oxen construct by fork, spade, and related digging materials. Locally it is named "Boyea" (Wolaita and Dawro). They believe that the construction of the cutoff drain has both production and conservation-oriented advantage. They intend to conserve inputs (seed and fertilizers) and soil loss and to divert runoff from home garden. A similar study by agrees with this study [12,20]. Sample respondents stated that, traditionally, farmers in the study area divert water from their cropped land to boundaries. The survey result depicts that, diverted water creates and exacerbates gullies, reduces the productive land size, and limits the free movement of man and livestock from field to field. In addition, farmers construct improved cutoff drains based on standard guidelines developed by the Ethiopian MoA. However, the difference exist is observed in technical aspect and the appropriateness of the structures. Although they complain, the researcher investigated fanya juu bund in the steep slopes of the study area. The construction of Fanya juu takes less space than soil bunds and accelerates bench development, thus, a complaint about space can be greatly reduced with Fanya juu terraces [21]. Respondents pointed out that they construct fanya juu from to reduce runoff velocity, halt soil erosion, and increase infiltration.

This study revealed that well managed and maintained soil bund, fanya juu, grass strip, and stone bunds gradually converts to bench terraces. Similar study conducted by agrees with this finding. However, in some cases, hillside terraces were constructed directly on sloppy and mountainous areas [15]. Finally, on the bed of the terrace, legume grasses and shrubs such oat, vetch, faba bean, field peas, and Cajanus cajan are planted to facilitate restoration. The study held by found that plantation of legume species might enhance recovery of species richness and promote their succession on degraded grasslands [22]. These implies that planting legumes could be an effective measure to accelerate the recovery process of the degraded lands. The result illustrates that the use of compost on degraded lands to facilitate the rate of rehabilitation.

The study shows that farmers practice single row brushwood check-dam. According to field observation, many of the check dams were not constructed well and lacks biological conservation measures. As a result, check-dams constructed in the study areas were found to be not effective. The result of pointed out that due to the deviation of the actual check dam from recommended standard, the amount of run-off from the up-slope areas of the watershed could not be readily dissipated by the existing check dams, which caused their collapse [23]. This also led to the formation of incisions on the gully floor and sides. These cosequences were recorded for this study (Figure 10).

To overcome the failure of the crops due to moisture stress and soil loss, farmers implementing contour furrows. Sample respondents pointed out that contour furrowing decrease runoff volume thereby enhancing water availability to crops. The reduction in runoff volume is attributed to depression storage in the furrows which gives time for infiltration. This is in line with study held by [24]. In the study area, contour furrow is commonly practiced on Maize fields and farmers used to construct contour furrow locally named 'shilshalo' with well-experienced oxen. To do so, they use yokes having a different height at planting time and shilshalo. There is about a 10 cm height difference exist between yokes (Figure 15). They use the longer yoke for shilshalo and the shorter one for plantation and land preparation. Furrow is purposely prepared in a straight line across the slope to harvest rainwater. Besides, there exist difference in width and depth between Digir they use for furrow and plantation. Traditional Digir used for shilshalo has about 30 cm depth and 50 cm width where ample rainwater can safely stagnate on the field. So that, during a dry spell, maize crops can face no or little moisture deficit. Furthermore, mulching and crop residue management is an important practice in the study areas (Figure 16).

Farmers in the study area practices mulching, crop residue management, and zero grazing's. The study shows that farmers use mulching material at dry season to maintain soil moisture, prevent soil pulverization and thereby reduce susceptibility to erosion and enhance soil fertility. Similarly, they use mulching materials during rainy seasons to improve soil structure, reduce raindrop impact and surface runoff velocity.

Furthermore, the study revealed that farmers practice various measures such as FYM, composting, green manure, intercropping, row planting, crop rotation, tied ridge, plantation of MPTS, and plantation of deep-rooted crops to replenish soil fertility in the meantime to reduce surface runoff (Table 5).

Name of structures	Description	Study area	Type	Remark
Soil bund (level and graded)	Introduced	Wolaita, Hadiya, K/ Tambaro and Dawro	Physical	-
Local bund (traditional)	Indigenous	Dawro	Physical	Each year farmers leave 0.5 – 1m width farm plot across the slope on cropped land
Stone bund (level and graded)	Introduced and indigenous	Wolaita, Hadiya, K/ Tambaro and Dawro	Physical	Based on availability of stone
Stone-faced soil bund	Introduced	Wolaita and Hadiya	Physical	-
Fanya juu	Introduced	Dawro, Wolaita, K/ Tambaro,	Physical	-
Bench terrace	Introduced	Dawro, Wolaita, K/ Tambaro, Hadiya	Physical	-
Check dams/brushwood, stone, sandbag, and gabion	Introduced	Dawro, Wolaita, Hadiya, K/Tambaro	Physical	-
Area closure	Introduced	Wolita, K/Tambaro, Dawro and Hadiya	Biological	Integrated with physical and biological soil and water conservation measures
Cutoff drain	Introduced and indigenous	Wolaita, Hadiya, K/ Tambaro and Dawro	Physical	-
Trench	Introduced	Dawro, Wolaita, K/ Tambaro, Hadiya	Physical	-
Micro basin	Introduced	Dawro, Wolaiata, K/Tambaro,	Physical	-
Grass strip	Introduced	Dawro, Wolaita, K/ Tambaro,	Biological	Desh, Elephant grass
Bund stabilizer	Introduced	Dawro, Wolaita, K/ Tambaro,	Biological	Banana, desho, Elephant grass, Pigeon pea
Contour furrow/ shilshalo	Indigenous	Dawro, Wolaita	Agronomic	Practices commonly used in a maize field
Contour farming	Indigenous	Dawro, Wolaita, K/ Tambaro, Hadiya	Agronomic	-
Live fence	Indigenous	Dawro,	Biological	*Jatropha curcus*
Improved fallow	Indigenous	Dawro, Wolaita	Agronomic	
Mulching and crop residue management	Indigenous	Dawro, Wolaita, K/ Tambaro,	Agronomic	Maize and sorghum residues, cutting the stalk of wheat, teff and barley from the top 15-20 cm and leaving animal dung and leaf of banana
Intercropping	Indigenous	Dawro, Wolaita, K/ Tambaro, Hadiya	Agronomic	Maize + Field pea, Enset + Coffee, Maize + Common bean
Crop rotation	Indigenous	Dawro, Wolaita, K/ Tambaro, Hadiya	Agronomic	Cereal with legumes
Communal pond	Introduced	Hadiya, K/Tambaro, Wolaita, Dawro	Physical	To irrigate vegetable crops and used as water points for livestock and hh consumption

Tree plantation across slope, gully, and croplands	Indigenous	Dawro, Wolaita, Hadiya, K/Tambaro	Biological	*Jatropha curucs, Erytrinica spp., Mangifera indica, Terminalia browni, Persia americana, Musa spp., Enset Ventricusem, Agave sisalana, Oxytenanthera abyssinica, Arundinaria alpina, Gravellia robusta, Manihot esculenta, Moringa spp., Acacia saligna, Acacia decurrence,*
Farm yard manure (FYM)	Indigenous	Dawro,	Agronomic	-
Row planting	Indigenous	Dawro, Wolaita	Agronomic	-
Composting	Indigenous	Dawro, K/Tambaro	Agronomic	-
Tie ridge	Introduced	Dawro, Wolaita, K/Tambaro,	Physical	-
Controlled and zero grazing	Indigenous and introduced	Dawro, K/Tambaro,	Agronomic	-
Waterway	Natural and Artificial	Wolaita, Dawro	Physical	-
Hillside terrace	Introduced	Wolaita, K/Tambaro, Dawro, Hadiya	Physical	-
Hand-dug wells	Introduced	K/Tambaro, Dawro	Physical	-

Table 5: Summary of SWC measures in the study area

7. Conclusions

Farmers in the study area have a good understanding of soil erosion, its causes, and the resulting reduction in land productivity. They emphasize that implementing soil and water conservation (SWC) measures is necessary to sustain and improve soil fertility and land productivity. The study found that various SWC measures, both indigenous and introduced, had been implemented by farmers in different land-use systems. However, certain practices such as traditional cutoff drain, soil bund, stone-faced soil bund, fanya juu, brushwood, and gabion check-dams face technical, social, and institutional difficulties. One major gap identified was the lack of attention given to indigenous conservation practices by different stakeholders including GOs, NGOs, and research institutes. Consequently, these practices were not modified, effective measures were not upscaled, and they were not circulated to other areas with similar agroecology and farming systems. Traditional conservation measures were found to worsen soil erosion and their construction did not consider impact on downstream. In particular, traditional cutoff-drain was found to be the most problematic, as it created gullies at the boundary and increased the size and depth of preexisting gullies. Technical defects were also observed in fanya juu and soil bunds in terms of channel depth and embankment height. This could be due to the time interval between implementation and evaluation periods, free grazing, lack of regular maintenance, improper design and construction, and deliberate destruction by landowners due to shortage and fragmentation of farmlands. In general, in situ soil moisture conservation measures were limited to closed areas and marginally degraded lands in the study area. Based on the findings, the following suggestions are important:

➢ Adequate consideration might be needed to improve and disseminate technically,
economically, socially, and ecologically viable indigenous SWC measures

➢ In situ rainwater harvesting measures need to be introduced in the home garden and
farmlands by integrating them with cereal crops to minimize crop failure and boost
productivity

➢ Appropriate strategies and policy directions for the sustainability of implemented SWC
measures should take the focus

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Conflict of Interest

The authors declare no conflict of interest.

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