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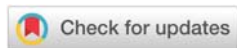
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Research Article

Technical evaluation of selected soil conservation practices and farmers' perception about soil erosion in Donbi Watershed, Wolaita Zone, Southern Ethiopia

Abstract

A study was conducted at Donbi watershed, Wolaita zone, southern Ethiopia to identify, describe and evaluate different introduced soil and water conservation practices and to assess farmers' perceptions about soil erosion and conservation measures. The necessary data were generated through field measurements and structured questionnaire survey, group discussion and transect walk. The structures were evaluated by comparing the field measurement result with the recommended dimensions. The results obtained showed that level soil bund and fanya juu were the dominant structures identified in the watershed. The technical evaluation of the structures showed that generally the spacing of soil bund was wider than the recommended while in most fanya juus within the acceptable range. Similarly, the channel depth of the structure in different parts of the watershed was smaller than the recommended. Farmers in the watershed are aware of the problem of soil erosion and the importance of conserving soil. They have also developed their own judgments about the relationship between different dimensions of bunds and soil erosion as a result of long field experience in their locality.

Introduction

Soil erosion is recognized as one of the most serious causes of soil degradation in Ethiopia [1-5]. And hence in highland areas of the country the crop yield and soil fertility levels are extremely low [6]. Annually about 1.5 to 2 billion soil loss rate is reported for the country [7,8]. Most of the factors contributing for soil erosion in the country are human induced [9,10]. Most cultivated lands in the hills and mountains of the country have suffered from loss of top soil, leaving bare stones. Gullies are observed everywhere in the deep soils [11]. It caused strong environmental impacts and major economic losses from decreased agricultural production and from off-site effects on infrastructure and water quality by sedimentation processes [12,13]. It has put a substantial threat in agriculture of the country. Out of a total surface area of 112 million hectares, the estimates made in the mid 1980s showed that about 27 million hectares are significantly eroded, 14 million hectares are seriously eroded and 2 million hectares have reached the point of no return [5,14].

To mitigate the effects of land degradation, mainly due to

soil erosion, the Ethiopian government intensified the effort to improve agricultural production by coordinating farmers to implement soil and water conservation practices [15,16]. Declining soil fertility, mainly soil erosion, is one of the most important issues that constrained the agricultural production of both the lowland and highlands of Wolaita zone caused by many combined factors of natural resource management [17]. Pound and Ejigu (2005) indicated some of the factors causing decline of soil fertility as clearing of forests, the removal of crop residues from the fields, land fragmentation, reduction of fallows, overgrazing, low fertilizer inputs, inadequate soil and water conservation measures, cropping of marginal lands and poor soil management. These factors have resulted in lower crop yields and lower livestock numbers leading to reduced food security and increased poverty.

In addition, in many places, there exist a mismatch between the area specific technical criteria (spacing, vertical interval, grading or leveling and others) of the soil conservation measures and its physical and climatic conditions. In fact, the soil conservation practices are recommended to a given area based on the physical (like slope, soil depth) and agro-

ecological condition, taking in to account the farmers opinion and participation regarding all the dimensions. As a result, in many farmlands the conservation measures are damaged and not effective in preventing the soil erosion. The follow up and maintenance of the conservation measures is less due to different reasons and this exacerbated the problem.

Therefore, evaluation of the field design condition and the performance of soil conservation measures are very much crucial to know the compatibility of the measures with their design specifications. To maximize the effectiveness of the conservation measures, it is advisable to consider the complex situation of the environment and to keep them with their design specifications. Consideration of farmers is also the important wing that should be considered that magnifies the effectiveness in soil conservation. This is because farmers invest on their land to conserve it based on their perception on both soil erosion and its conservation. Farmers who perceive soil conservation increases crop production felt the responsibility for its conservation [18]. In addition, farmers' decision to adopt soil conservation measures is not only influenced by their perception of erosion hazard but also on the types of structures and on their attributes [19]. Therefore the objectives of this study were i) to evaluate the technical aspects and functional status of selected soil conservation practices in reducing soil erosion and ii) to assess the farmers' perception towards the selected soil conservation practices

Methodology

Description of study area

The study area is located between 6°56'1'' to 6°56'4'' latitude and 37°39'5'' to 37°39'3'' longitude in the south western part of the Ethiopian highlands and at altitude between 1908 and 2100 m.a.s.l. and is part of the Omo drainage basin. The landscape of the watershed is mainly characterized by undulating topography with typical slope steepness of 10% to 20%. The total size of the study area is about 165ha.

The climate is classified as sub-humid (Weigel, 1986 cited in Von Gunten, 1993). The mean annual temperature is 20°C and the mean daily maximum and minimum are 23°C and 17°C, respectively. The mean annual total rainfall ranges between 1198 mm and 1762mm. The area has an extended period of long rains with two peaks in the month of April and August [20].

The dominant soil types of the study area is Eutric Nitisol characterized as dark red-brown soil with very deep, well drained and high water holding capacity [21,22].

The area is covered by annual crops thus with poor vegetation cover. However some indigenous and exotic scattered trees and shrubs are found scattered in the area. These trees are found along farm boundaries, stream banks, road sides and at the border of the farmlands.

Data collection methods

There is topographic and farming system variation within the watershed which eventually leads to variation in selection

of soil conservation measures. To manage this, the watershed was classified in to three sections as upper stream, middle stream and downstream with major variations in terms of slope steepness and farming system. The watershed has a convex shape surface and hence the upper stream is dominated by homestead and relatively flat to gentle sloping topography. The middle section is used mainly for cereal based crop production system. The cereals based crop production system, together with grazing lands, was also practiced in downstream part of the watershed. However, the slope steepness was up to 20% steeper than the other sections. Assessment of soil conservation measures were made in three sections separately to account for the variation due to slope as well as agricultural practices variation.

Transect walks across the watershed was conducted in order to obtain all the necessary extra biophysical information of the watershed. A group of eight people (five farmers, two development agents and the researcher) were involved in the transect walk. The famers were selected based on willingness, knowledge about the area, duration of stay in the watershed. Two transect walks were made; one along the upper stream part and the second between middle and downstream sections of the watershed. Identification of types of conservation measures and field measurements were made during the transect walk. Moreover, the, informal discussions with the farmers helped to acquire detail information.

During the transect walks, types and year of construction of the soil conservation measures were identified, coded by features in the farms and owner of the farmland recorded using a format developed for this purpose.

Eleven farm plots, seven farm plots with level soil bunds and four farm plots with level fanya juu, were selected in each part of the watershed for the field measurement and observation. These account to 10% of the total farms visited during the transect walk.

Field measurements were made on slope steepness, bund spacing, vertical interval, depth and width of excavation, soil depth and other topographic features, and field observation on types and status of the soil conservation measures. In each farmland, three different positions were considered: upper part, middle part and down parts. Three measurements of the above parameters were done on each structure and the average value was calculated for the three positions in the field. Finally, comparison of the field measurement for the parameter with the recommended specifications for such area was made and the performance of the structures was assessed.

Household survey was also done to assess the farmers' perception on the conservation measures. To represent the watershed a total of 17 household were randomly selected. This is about 10% of the households in the watershed. The questionnaire was pretested for consistency and clarity before launching the final survey. The major areas of investigation were about the farmers' perception on soil erosion, soil conservation and knowledge on parameters of conservation structures.

Simple descriptive statistics was applied to analyze data. The data analysis on field measurement was made by comparing field results with the technical standards specified for different topographic and agro-ecological conditions.

Results

Technical evaluation of physical soil conservation measures

The most important and widely used physical conservation measures in the watershed were soil bund and fanya juu which has been implemented since 1980's. In order to evaluate their technical status, performance and preferences by the farmers those with 2 years since their construction for level soil bunds and newly constructed for fanya juu were considered. Implementation of these structures considers agro-ecology, topography, and socio-economic factors [23-25]. Moreover, land use, and availability of construction materials are important.

Soil bund: The technical aspects selected for evaluation of level soil bund were spacing / vertical interval and layout on the contour. Other technical aspects were not considered due to the modification of those dimensions since their construction through the process of development.

Spacing and vertical interval are dependent one over the other. Spacing is the ground distance between two consecutive bunds and vertical interval is the height difference between two consecutive bunds. In principle, spacing is decided by the steepness of the slope and the runoff expected to generate in the area. However consent of the individual farmer would be crucial for the sustainability of the structure. Therefore, a compromise may be required between the farmers' interest and technical recommendation of spacing.

The measurements of the mean spacing and vertical interval of seven farm plots with level soil bund are presented in table 1 below.

Bund layout, gradient: The bunds considered for evaluation are claimed to be level, made on the contour. However it is common that due to poor layout bunds deviate from being level. The field measurement indicated that in all the selected farm plots, the bunds constructed were not laid along the contour (Table 2).

Fanya juu: Ditch depth, width and gradient. These are depth and width of basin excavation below the embankment. The depth and width of the ditch for level fanya juu for farmlands with slope steepness up to 10% is about 0.55m and it is 0.6m for farmlands of 10% to 20% slope steepness [23,24]. The field measurement on both of the parameters on the selected farm plots is shown in table 3.

Spacing and vertical interval

The technical parameters selected for evaluation of level fanya juu were spacing, vertical interval, ditch depth and width, embankment bund bottom and upper width, berm size, bund height and bund gradient. Field measurement of spacing

Table 1: Mean value of measured spacing (S) and vertical interval (VI) of level soil bund and farm slope steepness in upper, middle and lower sections.

Watershed position	Parameters	Field plots							Mean
		1	2	3	4	5	6	7	
Upper	VI (m)	2.2	2.3	2.5	2.8	3.8	4.3	6.1	3.4
	spacing (m)	31.7	29.6	24.9	24.6	24.1	23.5	22.9	25.9
	slope (%)	9.7	10.1	11.1	11.8	15.7	15.9	15.6	12.8
Middle	VI (m)	2.4	2.5	2.5	2.5	2.7	3.1	4.6	2.9
	spacing (m)	24.0	23.7	22.1	22.1	16.7	14.5	13.4	19.5
	slope (%)	10.8	13.0	13.1	14.6	16.8	19.2	20.5	15.4
Lower	VI (m)	3.0	3.4	3.4	3.5	3.6	4.5	4.8	3.7
	spacing (m)	31.0	27.5	26.7	24.5	22.6	19.0	12.2	23.4
	slope (%)	10.3	13.6	14.8	17.9	19.6	21.1	21.4	17.0

Table 2: Measured gradients of the soil bunds in the selected farm lands.

Watershed positions	Sample bunds	Farm fields						
		1	2	3	4	5	6	7
Upper	1	1.0	0.0	3.0	1.0	0.4	2.6	1.0
	2	0.8	0.2	3.0	0.9	0.2	2.0	1.2
	3	1.0	0.4	2.6	1.2	0.3	2.4	1.1
	Mean	0.9	0.2	2.9	1.0	0.3	2.3	1.1
Middle	1	0.4	1.0	1.2	0.8	0.2	4.0	1.0
	2	0.2	0.8	1.2	0.6	0.4	2.0	0.6
	3	0.3	0.5	1.2	0.8	0.2	1.6	0.8
	Mean	0.3	0.8	1.2	0.7	0.3	2.5	0.8
Lower	1	0.8	3.0	1.2	1.0	1.2	0.5	0.8
	2	0.6	2.8	1.0	1.0	1.2	0.2	1.2
	3	0.4	2.4	1.2	1.0	0.8	0.6	0.8
	Mean	0.6	2.7	1.1	1.0	1.1	0.4	0.9
Field measurement mean		0.6	1.2	1.7	0.9	0.5	1.8	0.9

and vertical interval on the selected fanya juu constructed farm plots in all the three parts of the watershed are shown in table 4.

Embankment height, upper width, bottom width and size of berm

These are dimensions related to the fanya juu embankment and their appropriate design is necessary for its better performance of the structure. In addition, these are dimensions that need special technical care because usually there is less participation of farmers in the field in their modification.

The field measurement on all of the indicated parameters on the selected farm plots of the watershed is shown below in the following table.

Functional status of bunds and related observable features in the farmlands

These are features in the farmlands and on the bund itself that indicate the functionality of the bunds in preventing soil erosion. In addition to the technical aspects, factors like stabilizing the bunds with vegetative materials and maintaining the structures in the case of damage are required to increase its functionality [23-25]. The selected features for the evaluation of the functionality of the bunds were damage to the bund, level erosion in the farmlands, and bunds' stabilization vegetative

materials. This evaluation was not done for fanya juu due to their short duration after construction and done for only soil bunds.

Farmers' perception of soil erosion related to bund parameters

Farmers were asked to give their opinion on the relationship between the measured bund parameters and soil erosion hazard. Their response in relation to the effect of bund parameters on soil erosion hazard is indicated in the following table 5.

Discussion

Technical evaluation of physical soil conservation measures

Soil bund: The measured parameters for soil bund from the field were compared with the recommended standards of spacing and vertical interval (VI) of level soil bund based on the slope of the field and the soil depth as given by Daniel (2001) and Lakew et al. (2005). The average surface soil depth measured at three watershed positions range from 0.82m to 0.87m and for such narrow range an average depth of 0.84m.

In the upper stream parts of the watershed, the average slope steepness of the selected farm plots is 12.8% (Table 1). Based on the average soil depth, the VI recommended for level soil bund is 1m to 1.2m [23] and 1m to 2m [24]. Therefore, compared to recommended values for such areas, the vertical interval maintained between the consecutive bunds is significantly higher than the recommended one for such farmland types. For farmland types with such slope steepness and soil depth

Table 3: Field measurements of ditch width, depth and gradient.

Watershed positions	Dimensions	Farm fields				Average	
		1	2	3	4		
Upper	Average ditch depth (m)	0.47	0.49	0.49	0.48	0.48	
	Average ditch width (m)	0.48	0.53	0.49	0.50	0.50	
	Average slope steepness (%)	13.78	8.33	16.22	12.76	12.78	
	Ditch Gradient (%)	Fanya juu 1	1	0.20	0	0.40	0.22
		Fanya juu 2	0.50	0	0.20	0.23	0.22
Fanya juu 3		0	0	0.10	0.03	0.22	
Average		0.50	0.07	0.10	0.22	0.22	
Middle	Average ditch depth (m)	0.49	0.48	0.50	0.50	0.49	
	Average ditch width (m)	0.58	0.49	0.49	0.52	0.52	
	Average slope steepness (%)	14.67	14.00	17.67	15.47	15.45	
	Ditch Gradient (%)	Fanya juu 1	0.02	0.4	0.01	0.14	0.14
		Fanya juu 2	0.01	0.2	0	0.07	0.07
Fanya juu 3		0.02	0.4	0.05	0.16	0.16	
Average		0.02	0.33	0.02	0.13	0.12	
Lower	Average ditch depth (m)	0.49	0.49	0.49	0.49	0.49	
	Average ditch width (m)	0.57	0.50	0.50	0.52	0.52	
	Average slope steepness (%)	15.64	21.44	21.11	19.41	19.40	
	Ditch Gradient (%)	Fanya juu 1	0	0	3	1.00	1.00
		Fanya juu 2	0	0.6	2.6	1.05	1.07
Fanya juu 3		0	0	2	0.65	0.67	
Average		0	0.20	2.53	0.90	0.91	

Table 4: Field measurements of spacing and vertical interval (VI) of fanya juu terrace.

Watershed positions	Dimensions	Farm fields				Average
		1	2	3	4	
Upper	Average vertical interval (m)	2.63	0.97	1.61	1.76	1.74
	Average spacing (m)	18.98	20.87	12.35	17.39	17.40
	Average slope steepness (%)	13.78	8.33	16.22	12.76	12.78
Middle	Average vertical interval (m)	1.15	2.51	4.09	2.72	2.62
	Average spacing (m)	20.62	18.40	20.25	19.74	19.76
	Average slope steepness (%)	14.67	14.00	17.67	15.47	15.45
Lower	Average vertical interval (m)	1.11	2.77	2.08	1.97	1.99
	Average spacing (m)	13.75	22.21	13.62	19.72	17.33
	Average slope steepness (%)	15.64	21.44	21.11	19.40	19.40

Table 5: Field measurement on embankment height, width and size of berm of fanya juu terrace.

Watershed position	Dimensions	Farm fields				Average
		1	2	3	4	
Upper	Average embankment height (m)	0.48	0.46	0.43	0.48	0.46
	Average embankment bottom width (m)	0.97	1.00	0.96	0.97	0.98
	Average embankment top width (m)	0.28	0.27	0.25	0.28	0.27
	berm size (m)	0.15	0.19	0.12	0.16	0.15
Middle	Average embankment height (m)	0.45	0.51	0.44	0.48	0.47
	Average embankment bottom width (m)	1.05	0.98	0.98	1.00	1.00
	Average embankment top width (m)	0.31	0.28	0.29	0.28	0.29
	berm size (m)	0.21	0.21	0.20	0.22	0.21
Lower	Average embankment height (m)	0.42	0.43	0.45	0.44	0.43
	Average embankment bottom width (m)	0.92	0.89	0.71	0.83	0.84
	Average embankment top width (m)	0.24	0.25	0.29	0.27	0.25
	berm size (m)	0.02	0.07	0.21	0.11	0.10

characteristics, the recommended spacing for level soil bund is 8m to 11m [23]. Similarly, the level bunds in the watershed constructed at wider spacing than the recommended ones for such farmland types.

The average slope steepness of the farm plots in the middle parts of the watershed was varied between 10.78% and 20.45% and the average one is 15.4% (table 1). Based on the average soil depth of the watershed and average slope steepness in this part watershed, the recommended vertical interval of level soil bunds is 1m to 1.4m [10] or 1m to 2m [24]. Like in upper section of the watershed, as compared to the recommended ones, the vertical interval between the consecutive bunds maintained higher in the watershed. The recommended spacing between two consecutive bunds for farm plots with the indicated slope steepness and soil depth characteristics is 7m to 10m. As compared to the average spacing between the consecutive bunds (Table 1), level soil bunds were constructed with wider spacing than the recommended ones.

For downstream parts of the watershed, the average slope steepness of the farmlands is about 17% which is higher than all the other parts of the watershed. Assuming the maximum vertical interval of 1.5m [23] and 2.5m [24], for such areas, the average value of the field measurement result has shown that the vertical intervals of the level soil bunds maintained higher than the recommended ones. For farmlands types with

the indicated characteristics of slope steepness and soil depth in the downstream parts, the recommended spacing between two consecutive bunds is 7m to 10m. Like in other sections of the watershed, the soil bunds are constructed in wider spacing than the recommended ones.

In general, the structure was constructed in the watershed with higher vertical interval and wider spacing than the recommended values for farmlands with the indicated slope and soil depth characteristics. This implies that the farmlands are susceptible to be damaged by soil erosion problems due to their improper design. As also observed in the farmlands, about 71% of the farmlands with soil bunds had soil erosion problems of various levels.

Bund layout, gradient

The mean gradient of the bunds (21 fields in total) in the different sections was ranged from 0.6% to 1.8% (Table 2). In the upper section, the bunds were graded to be about 0.2% to 2.9%, in the middle and lower sections the bunds were graded at 0.3% to 2.5% and 0.4% to 2.7%, respectively. Taking the mean values in the three sections, further analysis show that in over 75% of the cases the slope exceeded 0.5% which is more than the recommended minimum grade for graded structures. Six cases (29%) each are in range of 0.5-1% and 1-2% and four cases (19%) are in the gradient greater than 2%

Therefore, though the intention was to construct level soil bund, the field measurements have shown the bunds were constructed with some slope ranging from 0.2% to 2.9%. This implies that the farmlands are susceptible to be damaged by soil erosion caused by runoff channeled through the ditch. It was observed in the field that only in two fields there was natural drainage outlet that can serve as a waterway (gullies at the farm boundaries) otherwise all are without outlet. Thus under circumstance where there would require draining channeled water most farmers will suffer from the runoff. Moreover runoff that would benefit the farm being retained would be lost.

Fanya juu: Spacing and vertical interval. The measured parameters for fanya juu from the field were compared with the recommended standards of spacing and vertical interval (VI) of level fanya juu given by Daniel (2001) and Lakew et al. (2005) for farmlands with the indicated slope characteristics.

In the upper section of the watershed, the average slope steepness of the selected farm plots was varied between 8.33% and 16.22% with average of 12.78% (Table 3). According to Lakew et al (2005) the spacing to the consecutive fanya juu bunds is decided by discussing with farmers. However, the final spacing decided through discussion should maintain the vertical interval. The VI recommended by both Lakew et al. (2005) and Daniel (2001) for such farmlands is between 1m to 2m and the average spacing is about 12m. Therefore, compared to recommended values for such areas the vertical interval and spacing between the consecutive bunds maintained around the recommended value for such farmland types. Hence, in this section of the watershed if the structure is to be stabilized with

different vegetative materials, the damage to the farmlands and the structure is expected to be minimized and the acceptability by the farmers increased.

In the middle stream, the average slope steepness of the selected farm plots was varied between 14% and 17.67% with average of 15.45%. Similarly, the recommended VI and spacing for such farm plots is about 1m to 2m, and 12m, respectively [23,24]. As compared to these recommendations, both the spacing and VI in middle section of the watershed is maintained around recommended values for such farmland types.

The average slope steepness of the selected farm plots in the downstream parts of the watershed was varied between 15.64% and 21.44% with average of 19.40%. The average measured vertical interval and spacing was between 1.11m to 2.77 and 13.62m to 22.21m, respectively. The recommended VI for farmlands with such slope steepness is about 1.8m and the spacing is about 9.18m [23]. Unlike the other sections of the watershed, in this part of the watershed both the VI and spacing maintained out of the recommendation for farmlands with such topographic characteristics.

Ditch depth, width and gradient

As compared to the recommended values for such kind of farmlands the ditch depth of the structure in all the three parts of the watershed maintained at shallower depth than the recommended ones. However, the ditch width was maintained around values recommended for such kind of farmlands in middle and down parts of the watershed. This parameter was also maintained out of the recommendation in down parts of the watershed.

Gradient of the structure was the other factor that was considered for the evaluation. In all the three parts of the watershed, the structure was not constructed along the contour and it is graded with average slope gradient of 0.12% to 0.91% and it reached the slope gradient up to 3%. Hence, there may be unexpected flow following the gradient during intense rainfall.

Embankment height, upper width, bottom width and size of berm

Fanya juu embankment and related specification are indicated in different sources after repeated field observation and experiences. The recommended bund height for level fanya juu should be a minimum of 0.6m and its bottom and top width are 1-1.2m and 0.3-0.5m, respectively [24]. In Hurmi (1995), it is recommended that the space between the ditch and the beam (berm) is at least 25cm. According to Daniel (2001) the recommended height of the embankment is 0.65m and the size of the berm is 15cm to 20cm.

In the watershed, the average embankment height of the structure was varied between 0.43 to 0.47m. As compared to the recommended ones, in all the three parts of the watershed, the height of the embankment maintained smaller than that recommended values. Therefore, there might be an overtopping problem in the farm plots constructed with the fanya juu terrace due to the short embankment height.

Though there is some deviation, the embankment bottom width in upper and middle streams and embankment top width in middle stream of the watershed maintained around the recommended values. However, the embankment top width in upper and down streams and embankment bottom width in downstream maintained different than the recommended ones.

Regarding the space between the ditch and the beam (berm size), in all the three parts of the watershed the berm size is maintained at recommended range. However, in most of the farm plots the its size is around the lower limit that might result in returning of the excavated soil in to the ditch, that in turn shortens the life of the bund and result in frequent maintainace.

Functional status of bunds and related observable features in the farmlands

As observed during field measurement, all the soil bunds were stabilized to various levels with elephant and desho (*Pennisetum glaucifolium*) grasses. However, other features like damage to the bunds and erosion were observed in the farmlands.

In the upper and middle sections of the watershed, it was observed that stabilization increased the sustainability of the bunds. In about 71% of the selected farm plots, rills of various sizes were observed (Figure 1). However, in about only 32% of the farmlands the damage of various levels was observed in different sections of the bunds. Therefore, damage to the bunds was not as such the erosion in the farmlands.

However, in downstream parts of the watershed the cases were different. In about 42.9% of the selected farm plots, bunds had damage of various levels (Figure 2). Regarding erosion features in the farm plots, it was higher than both up and middle stream parts of the watershed. About 71s% of the selected farm plots had rill erosion problem and of them in about 40% rills of large size were observed. This could be related with wider spacing of the bunds than the recommended ones as indicated in previous sections.

Farmers' perception of soil erosion related to bund parameters

The change in perception of farmers in soil and water conservation practices in their farmlands directly related with the effectiveness of the structures [9,26,27]. Farmers have



Figure 1: Soil erosion in some of the farm plots the watershed.



Figure 2: Damage to soil bunds in some of the farm plots in the watershed.

different perception on the factors affecting the effectiveness of the structures and have a detailed knowledge of, and opinion about, what works best where. A complete rejection of level soil bund and high complaint on fanya juu by farmers due to improper design was reported Koga catchment of Ethiopia [28]. Farmers invest for structures when the problem exists and they are confident for its effectiveness in controlling soil erosion [29–32]. The households' response in relation between bunds specification and soil erosion shown as about 91% of the respondents with physical structures in their farmlands suggested that there is direct relation between bund spacing and soil erosion that soil erosion increase as spacing between the bunds increases (Table 6). About 79.5% of the respondents also indicated as soil erosion decreases as the embankment height increases and about 18.2% responded as soil erosion happened in their farmlands irrespective of embankment height. Regarding embankment width majority of the respondents (about 65.5%) said that it has no effect on the level of soil erosion. However, about 27.3% of the respondents said that soil erosion decrease as embankment width increases.

Regarding channel depth and width, about 31.8% and 36.4% of the respondents, respectively, had no opinion in the relation between soil erosion and channel depth and width. Similarly, about 34.1% of the respondents said that the depth and width of the channel had no effect on the level of soil erosion and the similar percentage of the respondents said that soil erosion decrease as channel depth increases. About 29.5% of the respondents also said that soil erosion decrease as channel width during construction increases. This indicates that majority of farmers selected had good awareness on the variability of soil erosion with bund dimensions.

Generally, farmers could relate the bund parameters with the level of soil erosion problem. Specially, in relation to the bund parameters which are non modifiable throughout its life (bund spacing), the opinion given by the farmers is towards scientific reality. Variable opinions given were on band parameters which are modifiable (embankment height and with, and channel width and depth) throughout their life time. This implies that farmers take long observation time to reach on conclusion on relation between bund parameters and soil erosion. But in general, currently farmers have knowledge on importance of keeping the dimensions at acceptable range to make it effective in preventing soil erosion problem.

Farmers were also suggesting their impression and preference on the dimensions of the structures on their

farms. The spacing of the structures were rated as wider than necessary by 68% of the farmers while only 11% of them were saying it is less than what it should be (Table 7). This result is somehow in line with what the field measurement result showed regarding bunds' spacing (especially level soil bund). The embankments height and width were considered just right by 72% and 88% of the farmers respectively. The households' response on the channel depth and width of the structures showed that about half of the respondents indicated both the channel width and depth were just right and in average about 46% of the respondents had no any opinion on both of the parameters. This finding interestingly suggested that farmers are more sensitive to the spacing of the structures which affect the width of the cultivable area than the embankments where they claim sizes are acceptable to them.

Conclusions and Recommendation

Both spacing and vertical interval between two consecutive bunds found larger than the recommended ones in all parts of the watershed. Though they have been contributing a lot in preventing soil erosion problem, this deviation resulted in some damages to the bund itself and erosion problems of various levels in the farmlands. However, the good stabilization of the bund with different vegetative materials is appropriate and serves well. But, for the future work in areas of soil bund construction in the watershed improvement should be made regarding spacing and vertical interval for better effectiveness of the structure.

Regarding the level fanya juu, in all parts of the watershed, the vertical interval was maintained around the recommended one. However, in some parts of the watershed, the spacing was wider than the recommended one. Similarly, in all the three parts of the watershed, the ditch depth of the structure was maintained shallower than that recommended one for such watershed types. Therefore, some improvement should be done for the future plan in this regard considering the recommended dimensions for effectiveness of the structure.

Table 6: Farmers response on the effect of bund parameters on soil erosion hazard.

Bund parameters	Effect on soil erosion due to increased bund parameters		
	Effect, %	No change (%)	I don't know (%)
Spacing	+90.90	--	9.10
Embankment height	- 79.50	18.20	2.30
Embankment width	- 27.30	65.90	6.80
Channel depth	- 34.10	34.10	31.80
Channel width	-29.50	34.10	36.40

Note: (+) indicate direct relationship while (-) indicate inverse relationship

Table 7: Farmers response on evaluation of dimensions in their farmlands.

Dimensions	Farmers suggestion, %			
	more	less	Just right	I don't know
Spacing	68.20	11.40	20.40	--
Embankment height	--	27.30	72.70	--
Channel depth	4.60	--	50.00	45.40
Channel width	4.60	--	47.70	47.70
Embankment width	4.60	--	88.60	6.80

Other dimensions such as channel width, embankment height, embankment upper and top width, berm size and gradient of the structure along the contour were generally maintained within the recommended ranges.

Generally, improvement should be made regarding spacing and vertical interval for soil bund, and channel depth and spacing for fanya juu for effectiveness of the structure. In addition, experts should be trained practically regarding dimensions of both soil bund and fanya juu. Farmers in the watershed have good awareness on the effect of soil conservation measures in preventing erosion and they could developed their own judgments up on the relationship between different dimensions of bunds and soil erosion after their long time observation in fields. This is a good opportunity for the planners to progress forward in areas of soil and water conservation in the study area.

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