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Benefits, limitations and sustainability of soil and water conservation structures in Omo-Gibe basin, Southwest Ethiopia

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ABSTRACT

Different types of soil and water conservation (SWC) structures were introduced to Ethiopia during the last four decades for abating water erosion and sustaining agricultural productivity. This study aimed to determine benefits, limitations and sustainability of SWC structures in the Toni and Bokole watersheds of the Omo Gibe basin. A household survey was conducted on a total of 201 households, which were selected by employing a multistage sampling procedure that covered six rural kebeles.[1] Moreover, six focus group discussions were conducted. The results revealed that more than 80% of respondents in Bokole watershed and all respondents in Toni watershed experienced moderate to severe soil erosion. Farmers were selective in accepting and implementing SWC structures depending on the local land characteristics. Stone bunds were widely implemented in Bokole watershed where rock fragments are abundant and *Fanya juu* and soil bunds were widely practiced in Toni watershed where rock fragments are not available. Owing to labor intensiveness of the SWC structures, more than 82% of respondents in Bokole and 54% in Toni perceived that labor shortage was a challenge for construction and maintenance. More than 74% of the adopter farmers were also concerned about the loss of cultivable land due to the construction of SWC structures. Number of cattle owned ($p < 0.05$) and having administrative responsibility in the kebele ($p < 0.1$) significantly and negatively influenced construction of the SWC structures in Bokole watershed. Runoff overtopping, livestock trampling and cultivation practices were mentioned as the causes of damages for the SWC structures in both watersheds. In Bokole watershed, 92% of the respondents indicated that they repaired the broken SWC structures to sustain their benefits. But 62% of respondents in Toni watershed did not repair. The effort of repairing the SWC structures was significantly ($p < 0.05$) and negatively influenced by farmland area in Bokole watershed and by education level in Toni watershed. The respondents' preferences of SWC structures, rate of adoption, willingness to repair and factors affecting adoption and repairing were slightly different in Bokole watershed when compared with Toni watershed. Thus, we concluded that effective implementation and sustainability of SWC structures should critically consider the land users' socio-economic and environmental intricacy.

1. Introduction

Land degradation associated with soil erosion has affected more than 3 billion hectares of the global land area (Lal 2014), and affects more than 3 billion people (Nkonya et al., 2016). This notably challenges agricultural productivity (Borrellia et al., 2016) and influences livelihoods of more than 1 billion people (ELD Initiative, UNEP, 2015). African agriculture remains most threatened by land degradation and more than 60% of its cropland is affected at various scales (Muchena et al., 2005).

In Ethiopia, the highlands are the most productive parts of the country. These areas comprise about 45% of the country and are home to more than 80% of the population (Amsalu and De Graaff, 2007; Teshome et al., 2013). However, the highlands are characterized by rugged topographic settings, which are prone to land degradation by water erosion. Land degradation due to soil erosion has often been accelerated by exploitative and inappropriate land use and management practices (Shiferaw and Holden, 1999; Osman and Sauerborn, 2001; Tadesse, 2001; Bewket, 2007; Adgo et al., 2013). The extreme weather conditions that exhibit intense rainfall events are also causing enhanced water erosion. Recent studies predicted more extreme weather conditions in the future that may aggravate water erosion

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[1] a smallest local administrative unit.

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(IPCC, 2014; Muluneh et al., 2015). The resultant accelerated and intolerable water erosion remains a principal challenge and puts much strain on the livelihoods and food security of the rural poor (Birhanu and Meseret, 2013). Moreover, the offsite effect of soil erosion such as siltation in reservoir has been affecting hydroelectric power production, which is the major sources of energy in the country (Wolancho, 2012). The prevalent siltation effects on irrigation dams, inland lakes, and grazing and cultivated lands also impair the quality and productivity of those ecosystems.

Appropriate soil and water conservation (SWC) measures have an important role in controlling soil loss and its consequences. In Ethiopia, traditional SWC practices including stone terraces and agronomic measures have been historically practiced (Lundgren, 1993; Shiferaw and Holden, 1999; Osman and Sauerborn, 2001; Bekele and Drake, 2003; Amsalu and De Graaff, 2007; Bewket, 2007; Wolka, 2015). However, the roles of SWC technologies for environmental protection and sustainable agricultural production have been recognized only in recent decades, especially after the 1970s and 1980s devastating droughts and related famine (Lundgren, 1993; Shiferaw and Holden, 1999; Bekele and Drake, 2003; Bewket, 2007). In 1980s, a variety of SWC structures such as soil bunds, stone bunds, and *Fanya juu*[2] were developed and promoted (Hurni, 1986; Desta et al., 2005). A massive SWC development program was initiated (Bewket, 2007), which was scaled up later on (Wolka, 2015).

Several site-specific studies indicated the positive effects of various SWC structures in different parts of the country including reduction of soil loss (Tesfaye, 1988; Gebremichael et al., 2005; Vancampenhout et al., 2006; Teshome et al., 2013; Adimassu et al., 2014; Mengistu et al., 2016) and improvement of crop yields (Vancampenhout et al., 2006; Alemayehu et al., 2006; Nyssen et al., 2007; Teshome et al., 2013). Despite the recognized positive effects, poor adoption and management of the introduced and widely advocated SWC structures has affected the sustainability of the implemented interventions (Shiferaw and Holden, 1998; Amsalu and De Graaff, 2007; Bewket, 2007; Wolka and Negash, 2014). Sustainability, in the context of this article, refers to building SWC structures such as soil bunds, *Fanya juu,* and stone bunds and persisting the built structures by repairing (when required) to ensure its proper functioning and gradual development to a series of gentle/flat surface called bench terrace.

Various socio-economic, institutional and biophysical elements have influenced the construction and management of SWC structures in the country. In earlier decades, especially in areas prone to recurrent droughts, soil erosion, land degradation and food insecurity, implementations of the SWC structures were undertaken following the food for work scheme (Shiferaw and Holden, 1998; Shiferaw and Holden, 1999; Bekele, 2003; Amsalu and De Graaff, 2007; Bewket, 2007; Kassie et al., 2008; Birhanu and Meseret, 2013; Asmame, 2014). In this scheme, the landowners were provided with food grains and cash for the labor they applied in construction of SWC structures including in their own plots of cultivated lands. This might have negatively affected the sustainability and replication of the interventions. In addition, limited participation of stakeholders in the required steps of planning and management of SWC structures are commonly mentioned as the cause for poor replication and repairing of the introduced SWC structures (Bewket, 2007; De Graaff et al., 2008; Kassie et al., 2008; Kato et al., 2011; Ali and Surur, 2012; Birhanu and Meseret, 2013; Teshome et al., 2013; Asmame, 2014). Several site-specific studies listed a number of factors influencing the adoption and repairing of SWC structures. For instance, the effects of perceived seriousness of erosion, labor availability, and farm land size on construction and repairing of SWC structures were reported (Tadesse and Belay, 2004; Birhanu and Meseret, 2013; Asmame, 2014). Moreover, land tenure and extension services (Asmame, 2014), access to training, membership in local organizations, number of cattle owned, educational level, and off-farm income were indicated as reason for influencing adoption of the SWC structures (Tefera and Sterk, 2010; Birhanu and Meseret, 2013). In general, the influences of these factors on adoption and repairing SWC structures have been site specific and dynamic depending on social, economic and physical circumstances (Amsalu and De Graaff, 2007; Anley et al., 2007; Bewket, 2007).

The Omo-Gibe basin is one of the most important river basins in Ethiopia where three hydroelectric dams and huge irrigation projects have been constructed. The basin attracted global interest as the Omo is the single perennial river that feeds the only permanent and largest desert lake (lake Turkana) of the world. The basin has several watershed areas where there are extensive smallholder-based crop and livestock production systems. Bokole and Toni watershed areas represent part of the Omo-Gibe basin in Southwest Ethiopia. In Bokole watershed, stone bunds have been practiced traditionally since many decades. In addition, more recently, the government introduced other SWC structures such as soil bunds and *Fanya juu* terraces and promoted implementation of stone bunds. The fundamental aims of the introduced and promoted SWC structures in Bokole watershed were reducing land degradation, improving food security and reducing downstream siltation. Soil bunds and *Fanya juu* terraces were also introduced recently in the neighboring Toni watershed mainly by non-governmental organizations such as Action-aid Ethiopia. In both watersheds, the introduced and promoted SWC structures were mainly designed, demonstrated and monitored by the natural resource conservation experts at the office of agriculture and natural resource development. The traditional SWC structures (e.g. stone bunds in Bokole watershed) have been practiced in the small area by the farmers' own labor and experiences. In both watersheds, adoption of the introduced and promoted SWC structures was driven by grain and money incentives. Presently, the public campaign works for dissemination of SWC activities has also been implemented in both watersheds. This is part of the national strategy that has been implemented for about five years, which requires 30 days of free labor of the local people during the off-season of every year (Wolka, 2015). These two watersheds represent most of the biophysical conditions in the Omo-Gibe basin. Because they comprise: i) a range of agro-ecological conditions, ii) most of the indigenous and introduced SWC techniques and schemes of implementation that are common in the basin, iii) an undulating and steep sloping topography, and iv) the crop-livestock mixed economic activities of the rural areas that are common throughout the basin. Furthermore, the Bokole watershed drains directly to Gibe III hydroelectric dam on Omo river, which is roughly at the middle of the basin.

The success and sustainability of anticipated benefits of those extensively constructed SWC structures depend on the level of its replication and repairing by the farmers. However, the site- specific benefits and challenges of those structures were less studied in Ethiopia in general and in these watersheds in particular. Thus, there is a lack of information about the local peoples' perceptions on the construction, benefits, limitations, and maintenance of the introduced SWC structures. Thus, this study was aimed to i) determine the farmers' perception of erosion problems and interest in SWC structures in the Bokole and Toni watersheds, ii) evaluate the perceived benefits and limitations of constructed SWC structures, and iii) assess the causes of damage to SWC structures and the communities' efforts to repair and sustain the implemented SWC structures.

2. Materials and methods

2.1. Site description

The study was conducted at Bokole and Toni watersheds, which are part of the Omo-Gibe basin in Ethiopia and are located at about 500 km in southwest direction from the capital Addis Ababa. The Omo-Gibe

[2] A SWC structure with embankment or a bund at the upslope part and a ditch on the down slope side.

basin is located between 5° 31′ to 10° 54′ N and 33° 0′ to 36° 17′ E and covers about 79,000 km^2 of land area in South and Southwest Ethiopia. The Omo-Gibe river is the third largest perennial river in terms of water volume in Ethiopia, next to the Blue Nile and Baro Akobo, with a mean annual surface water flow of 17 billion m^3 (MWE, 2016). In this basin, the Ethiopian government has already built three hydroelectric dams (Gibe I, Gibe II and Gibe III), and the fourth dam (Koysha) is under construction and planned to generate additional hydropower (Gebresenbet, 2015). The basin drains to Turkana lake, which is the world's largest and permanent desert lake (Avery, 2010), and borders Ethiopia and Kenya. The Omo-Gibe basin is a major source of fresh water to this lake (Avery, 2010). The Omo-Kuraz sugar project of Ethiopia also uses the Omo river for irrigating more than two hundred thousand hectares of sugar plantations. Accordingly, this basin has been well recognized for its economic, social, hydrological, ecological and political importance for both Ethiopia and Kenya.

The Bokole watershed lies within 6° 55′–7° 01′ N latitude and 37° 15′–37° 19′ E longitude. Bokole watershed covers an area of about 54 km^2 with elevation varying from 1160 to 2400 m above sea level. The major landscape of this watershed is characterized by rugged topography. About 57% of the watershed area has slopes in the range of 20–45%, and are prone to water erosion. The annual average rainfall at Gessa Chare meteorological station, which is at the upper part of Bokole watershed and at about 5 km from the water divide with Toni watershed, is 1746 mm. The annual average rainfall in the lower part of Bokole watershed is about 1500 mm (SNNPRS-BoFED, 2004). In the upper part of Bokole watershed, the annual mean minimum temperature is 12.2 °C, whereas the mean annual maximum temperature is 21.9 °C. The average temperature for the lower part of Bokole watershed varies from 22.6 to 25.0 °C (SNNPRS-BoFED, 2004). Bokole watershed is drained by the Bokole river that flows to the Gibe III hydroelectric dam that was built on the Omo river.

Toni watershed is located between 6° 58′ to 7° 01′ N latitude and 37° 06′ to 37° 14′ E longitude (Fig. 1). It covers 19.1 km^2 land area, and its elevation varies between 1724 and 2412 m above sea level. Slopes of less than 20% characterize most of the watershed area (about 78%). Thus, compared to the Bokole watershed, Toni watershed is at a higher elevation, and its topography is less steep, which results in a relatively lower risk of water erosion. The climatic conditions of Toni watershed are roughly similar with upper part of Bokole watershed. Toni watershed is part of the Mensa river catchment and flows into the Omo river, but at a lower elevation compared to the Bokole river.

The soils of both watersheds are categorized mainly as Dystric Nitosols and Orthic Acrisols (SNNPRS-BoFED, 2004). In both watersheds, livelihoods of the community dominantly rely on agricultural activities, including crop cultivation and livestock keeping. The agricultural crops such as bean (*Vicia faba* L.), sorghum (*Sorghum bicolor* (L.) Moench), haricot bean (*Phaseolus vulgaris* L.), maize (*Zea mays L.*), pea (*Pisum sativum* L), groundnut (*Arachis hypogaea* L.), teff (*Eragrostis tef* Zucc.), barley (*Hordeum vulgare* L.), and wheat (*Triticum aestivum* L.) are cultivated dominantly as rain-fed crops. The rainfall pattern in both watersheds favors two cropping seasons which are categorized as: i) 'Belg', a crop growing season from February to May, which receives about 32% of the mean annual rainfall; ii) 'Meher', a cropping season from June to September that receives about 52% of the mean annual rainfall. Natural pastures are the dominant sources of livestock feed but communal grazing land is rarely available. Most households usually allocate a piece of marginal land as pasture for livestock feeding, and use crop residues and leaf of Enset (*Ensete ventricosum*) for supplementing livestock feed in the dry season (Wolka et al., 2013).

In both watersheds, traditional land and water management such as short fallowing, crop rotation, traditional cut-off drains, and manure applications have commonly been practiced. In some areas of the middle and lower watersheds of Bokole, rock outcrops provide

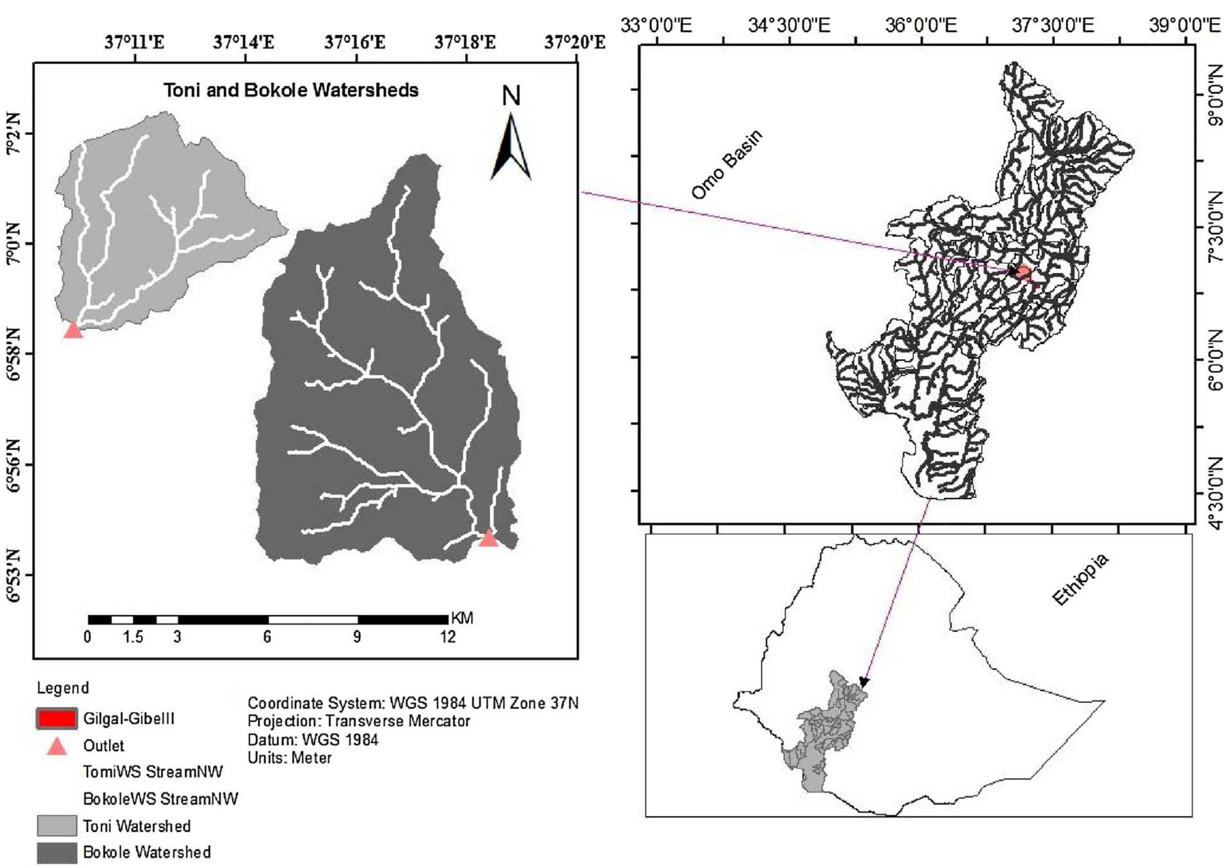

Fig. 1. Location map of the Bokole and Toni watersheds in Southwest Ethiopia.

Table 1
Distribution of sample HHs over the study kebeles in Bokole and Toni watersheds, Southwest Ethiopia.

Watershed	Kebeles	Relative position in the watershed	Total HHs (no)	Sample size		
				Adopter (no)	Non-adopter (no)	Total
Bokole	Gessa Chare	Upper	312	14	17	31
	Ela Bacho	Middle	407	22	19	41
	Subo Tulama	Lower	409	37	3	40
Toni	Tulama Tama	Upper to middle	283	15	13	28
	Tulama Kae	Upper to middle	314	22	9	31
	Mada Kuyili	Upper to lower	302	15	15	30
Total			2027	125	76	201

sufficient material for the construction of stone bunds. Traditionally, stone bunds have been constructed for several years in those parts of the Bokole watershed, mainly to get rid of rocks from the surface of cultivable lands. The traditional stone bunds are built by aligning them along the contour in homesteads and other cultivable plots. The government-employed experts introduced the design and implementation of cut-off drains, *Fanya juu*, contour soil bunds, and contour stone bunds (Wolka and Negash, 2014). These expert-lead SWC technologies were promoted and introduced to both Bokole and Toni watersheds through an incentive-based approach, for instance, by providing grain and money incentives.

2.2. Sampling technique

Part of the study comprised households (HHs) interviews. A stratified random sampling method was applied for selecting sample HHs in Toni and Bokole watersheds. In each watershed, three rural kebeles were identified and selected based on their representations of the different sections of the watershed areas. Furthermore, in each kebele, households who have SWC structures such as bunds and *Fanya juu* terraces on their land (adopters) and those without (non-adopters) were identified and categorized. The lowest and highest proportions of non-adopter HHs were observed in Subo Tulama and Gessa Chare kebeles of Bokole watershed, respectively (Table 1). After this categorization, about 10% of the adopter HHs was selected randomly. Similarly, about 10% of non-adopter HHs was selected randomly. Following this procedure, in Bokole watershed, a total of 112 HHs were selected from three kebeles (31, 41, and 40 HHs from Gessa Chare, Ela Bacho, and Subo Tulama kebeles, respectively). Similarly, in Toni watershed, a total of 89 HHs were randomly selected from three kebeles (28, 31, and 30 HHs from Tulama Tama, Tulama Kae and Mada Kuyili kebeles, respectively) (Table 1). In general, based on the proportionate sampling for adopters and non-adopters, it appears that in both watersheds there were a higher number of adopters than non-adopters.

In addition to the HHs interviews, focus group discussions (FGD) were held. In each kebele, focus group discussants were selected purposively. The HH heads were selected based on their experiences and knowledge about the study area and representativeness for the different parts of the study kebele. Six FGDs, one FGD per kebele, were undertaken with a group of ten HH heads each. In addition, a total of nine experts of agriculture and natural resources, who were working at kebele or woreda[3] levels, were subjectively selected for discussion based on their involvement in introducing and monitoring the SWC structures in the considered watersheds.

2.3. Method of data collection

2.3.1. Focus group discussions

The checklist-guided discussions with focus group members focused on seriousness of soil erosion problems, and the past and present SWC activities. Specifically, the objectives and importance of SWC structures, the approach by which the SWC structures were introduced, and the effects of SWC structures on controlling soil erosion and improving crop yield were discussed. Finally, challenges and limitations in building and repairing the structures, and community commitment to replicate and repair the introduced structures were evaluated.

The discussions held with experts were mainly used to address issues related to the approaches they followed during planning and implementing SWC structures, challenges in the process of implementing activities, and observed effects after building structures. Outcomes of discussions with agricultural and natural resource experts and farmers' key informants helped to substantiate the individual interviews.

2.3.2. Household interview

A pre-tested questionnaire consisting of multiple choice and open-ended questions was used to collect data from the selected HHs. The issues addressed in the questionnaire encompass fundamental socio-economic characteristics, seriousness of soil erosion problems, types of built SWC structures, reasons for choosing and implementing the SWC structures, recognized effects and advantages of built SWC structures, and favorable situations at HHs level that support building or rebuilding of the SWC structures. In addition, challenges in building the SWC structures, limitations of the SWC structures, workability of those structures by the HHs, their susceptibility to damage, HHs efforts to repair damaged structures, and the factors that determine the repair of SWC structures were considered.

2.4. Methods of data analyses

The collected data were analyzed and compared using percentages, calculating means, and by applying the chi-square test using SPSS version 20 (IBM SPSS, 2011). In the chi-square analysis the following variables were analyzed for significant differences: influence of age, number of household members, administrative responsibility in kebele, number of cattle owned, education level, farmland area, frequency of visit by development agents, perceived severity of soil erosion, workability of introduced SWC structures, and farmers' efforts to construct and repair the SWC structures.

3. Results and discussions

3.1. Socio-economic characteristics

In both Bokole and Toni watersheds, SWC is highly important because the livelihood and economic activities of HHs rely majorly on agriculture, especially on crop and livestock production. In both watersheds, a higher proportion of SWC adopter and non-adopter heads of HHs had an age below 45 years (Table 2), and only a few of the respondents were above 60 years. This indicates that a higher proportion of the heads of HHs can engage in construction and repairing of labor-intensive SWC structures, as younger persons are stronger. In addition, the large family size of most of the HHs shows the potential availability

[3] an administrative level comprising many kebeles and roughly equivalent to district.

Table 2
Basic socio-economic characteristics of the respondents in Bokole and Toni watersheds, Southwest Ethiopia.

HH socio-economic characteristics		Bokole watershed		Toni watershed	
		Adopter (%) (n = 73)	Non-adopter (%) (n = 39)	Adopter (%) (n = 52)	Non-adopter (%) (n = 37)
Age of HH head (year)	≤30	30.1	41.0	25.0	10.8
	31–45	35.6	38.5	38.5	51.4
	46–60	21.9	17.9	23.1	27.0
	> 60	12.3	2.6	13.5	10.8
Family size (no)	≤4	6.8	10.3	5.8	13.5
	5–7	38.4	38.5	38.5	35.1
	8–10	42.5	43.6	36.5	29.7
	> 10	12.3	7.7	19.2	21.6
Major sources of income	Food crop	79.5	84.6	90.5	91.9
	Livestock	74.0	69.2	82.7	73.0
	Cash crop	41.1	51.3	11.5	2.7
	Tree products	21.9	28.2	26.9	27.0
Cattle (no)	≤3	26.0	41.0	38.5	48.6
	4–6	45.2	28.2	46.2	40.5
	7–9	20.5	7.7	5.8	8.1
	> 9	8.2	23.1	9.6	2.7
Land area (ha)	≤0.5	35.6	48.7	51.9	55.6
	0.5–1.0	6.8	15.4	3.8	2.8
	1.0–1.5	5.5	7.7	7.7	8.3
	1.5–2.0	13.7	7.7	11.5	11.1
	> 2.0	38.4	20.5	25.0	22.2
Education status of HH head	Illiterate	52.1	41.0	28.8	48.6
	Grade 1–4	24.7	17.9	32.7	27.0
	Grade 5–8	15.1	30.8	25.0	13.5
	≥Grade 9	8.2	10.3	13.5	10.8

of labor force as some of the HH members can help in SWC activities. The formal education level of the majority of respondents is low, which probably indicates that a higher proportion of respondents will remain in agricultural activities for their economic and livelihood needs.

In both watersheds, a great proportion of respondents owned a small farmland area (≤1.0 ha, Table 2). This, on one hand, can motivate respondents to build the SWC structures for improving or maintaining the productivity in a small area. On the other hand, the SWC structures occupy cultivable area, which makes the SWC structures less attractive.

3.2. Perceptions on water erosion and interest in SWC structures

In both Bokole and Toni watersheds, more than 80% of respondents perceived moderate to very severe water erosion on their cultivated lands (Table 3). This was also confirmed by the focus group discussants who agreed that there was severe water erosion. Practically, land users commonly notice two main water erosion features, namely rills and gullies. Thus, the perceived moderate to very severe water erosion was mainly by considering visible features of erosion on cultivated lands, which was also used by farmers for erosion assessment in Kenya (Okoba and Sterk, 2006; Okoba et al., 2007) and Tanzania (Vigiak et al., 2005; Tenge et al., 2007). The actual soil loss can even be higher than the perceived severity when splash and sheet erosion are considered as well. Bewket and Sterk (2002) indicated that respondents in the Chemoga watershed, Central Ethiopia, did not consider less noticeable forms of soil erosion such as splash and sheet erosion. Amsalu and De Graaff (2007) also reported that farmers recognized only visible signs of soil erosion in the Beressa watershed, central highlands of Ethiopia.

The perceived severe water erosion might have raised interest of many farmers to accept the promoted SWC structures (Table 3). The focus group discussants unanimously agreed that water erosion is a critical challenge causing significant yield loss and thus erosion control at least by using traditional measure like cutoff drains is necessary to reduce yield losses. This stresses the prevalence of surface runoff in the area and the need for controlling it by using traditional techniques, even before the new technologies were introduced to this watershed. Studies in different parts of Ethiopia including central (Shiferaw and Holden, 1998), southeast (Asrat et al., 2004), south (Tadesse and Belay, 2004), and north (Asmame, 2014; Tesfaye et al., 2014) revealed that perceived soil losses encouraged farmers' construction of the SWC structures. Similar results were reported from Niger (Wildemeersch et al., 2015) and Tanzania (Mbaga-Semgalawe and Folmer, 2000; Tenge et al., 2004). However, Bewket and Sterk (2002) and Tefera and Sterk (2010) showed that farmers' perceptions on the severity of soil erosion may not always result in construction of the promoted SWC structures. Moreover, Wickama et al. (2015) reported a low rate of SWC adoption for the West Usambara highlands in Tanzania, despite the serious erosion problems and the many efforts to promote SWC measures.

Many farmers accepted and practiced some of the incentive-based SWC structures due to repeated promotion, material availability and perceived severity of water erosion. In Toni watershed, most adopters practiced soil bunds while some adopters had *Fanya juu* terraces. In Bokole watershed, a higher proportion of adopters had built stone bunds and nearly half of respondents practiced soil bunds (Table 3; Fig. 2). The availability of rocks on farmlands and the observed durability of different types of the SWC structures could determine choice of SWC structures. In Toni watershed and in the upper part of Bokole watershed, rocks are not available, which limits the construction of stone bunds. Accordingly, in those areas, soil bunds were widely implemented. The stone bunds were commonly practiced in the lower and middle Bokole watershed where rocks are abundant on cultivated land. In addition, focus group discussants in the middle and lower parts of the Bokole watershed indicated that they prefer stone bunds to soil bunds and *Fanya juu* terraces as stone bunds can serve longer periods. *Fanya juu* is an alternative option to soil bunds but it is less popular in Bokole watershed for three reasons. First, its embankment is exposed to damage as surface runoff hits it before flowing to the channel. Second, it requires high labor for throwing soil uphill. Finally, its embankment is less stable on sandy soils and steeper slopes. Bewket and Sterk (2002) also reported that farmers' in Chemoga watershed disliked this technology because of its vulnerability to accumulated surface runoff. However, farmers' focus group discussants in Toni watershed indicated that the *Fanya juu* has benefits of enhancing crop productivity at its upslope side where runoff and sediment accumulates. They prefer it for gentle sloping areas where it cannot be easily broken. According to Morgan (1986), *Fanya juu* can be constructed on land with slope of less than 26°.

During construction of SWC structures, about half of the respondents in Bokole and all respondents in Toni watersheds used their HH's labor (Table 3). In addition, availability of government support and advisory service might have contributed to the observed adoption of the SWC structures. The government support can help in promoting the introduced SWC technologies and increase interest in building the SWC structures. An assessment carried out in Australia found that properly planned and implemented incentives can be successful in inspiring land-users to accept and continuously practice the new SWC structures (Sanders and Dannis, 1999).

3.3. Perceived benefits and limitations of SWC structures

In both watersheds, a higher proportion of respondents perceived benefits of the SWC structures encompassing reduced surface runoff and

Table 3
Perceived severity of water erosion and implementing the SWC structures in Bokole and Toni watersheds, Southwest Ethiopia.

Perception on soil erosion and adopted SWC conservation structures		Bokole Watershed		Toni watershed	
		Adopters (%) (n = 73)	Non-adopters (%) (n = 39)	Adopters (%) (n = 52)	Non-adopters (%) (n = 37)
Perceived severity of water erosion	Very severe	31.9	31.4	90.2	90.9
	Severe	20.8	45.8	5.9	0
	Moderate	30.6	10.3	2.0	0
	Slight	16.7	12.5	2.0	9.1
Types of structures adopted	Soil bund	49.3		92.3	
	Stone bund	75.3		1.9	
	Fanya juu	1.4		30.8	
	Check dam	6.8		0	
	Cut off drain	1.4		0	
HHs contribution in building SWC structures	Labor	52.1	100		
	Material	12.3	3.8		
	Food and coffee	0	5.8		
Perceived favorable situation to build SWC structures	Labor available at HH	41.9	12.8	53.8	18.9
	Advisory service	83.8	84.6	75.0	75.7
	Government support	75.7	61.5	73.1	29.7

soil loss, moisture conservation, maintaining soil fertility and enhancing crop productivity (Table 4). In both watersheds, focus group discussants unanimously agreed on the positive roles of SWC structures in reducing soil erosion and improving crop yields. Practically, the SWC structures become series of physical barriers against surface runoff and soil erosion. The SWC structures reduce slope length and thus reduce the volume of surface runoff, which lowers the sediment transport capacity. Gradually, some of the introduced SWC structures form bench terraces and reduce the slope gradient that could impede surface runoff and ultimately reduce cumulative soil loss from a given agricultural land and maintain soil fertility. Other studies in different parts of Ethiopia indicated that SWC structures reduced soil loss (Wolka et al., 2013; Adimassu et al., 2014; Mengistu et al., 2016), which was also reported from Tanzania (Tenge et al., 2011; Wickama et al., 2014, 2015).

The perceived high soil moisture in croplands with SWC structures is due to reduced surface runoff and increased infiltration. In moisture stressed areas, this role of SWC structures is critically important for crop production (Alemayehu et al., 2006; Kassie et al., 2008; Biazin et al., 2012). Thus, the benefits of SWC structures on reducing surface runoff and soil loss, and increasing soil moisture were perceived to positively contribute to crop production. Accordingly, a higher proportion of the respondents in both watersheds perceived that the SWC structures increase crop production. Previous studies in different parts of Ethiopia also highlighted those positive roles of the structures (Alemayehu et al., 2006; Nyssen et al., 2007; Ayalew, 2011, Teshome et al., 2013).

In the lower part of Bokole watershed, nearly half of the respondents perceived that construction of the SWC structures can reduce rock outcrop from cultivable land (Table 4). In this area, collecting rock fragments to construct stone bunds was perceived as an additional advantage because they occupy the land surface where crops grow. On the other hand, when some rocks remain on cultivated lands they could serve as mulch and retain soil moisture. In addition, rocks could reduce soil erosion as they form physical barriers for splash impacts and surface runoff. Nyssen et al. (2007) also showed that removal of small rocks from cultivated hill-slopes increases the risk of water erosion. Thus, excessive removal of rocks from cropland for constructing stone bunds might aggravate water erosion in the inter-structure areas.

Despite the perceived benefits of the SWC structures, several perceived challenges and limitations disfavor farmers' construction and repairing. For instance, more than 80% of adopter and non-adopter respondents in Bokole watershed assumed that they have labor shortage at their HHs to implement the SWC structures by their own, which is because of the labor-intensive nature of the SWC structures (Table 4). More than 54% of respondents in Toni watershed perceived labor shortage as a major constraint to the adoption of the SWC structures. In both watersheds, focus group discussants underlined intensive labor demand of the SWC structures as a challenge especially during their construction. The farmers' response on a high labor demand of the SWC structures is a practical challenge that can reduce interest of their construction and repairing. According to Desta et al. (2005) soil bunds, *Fanya juu* and stone bunds demand a construction labor force of 150, 200 and 250 persons day^{-1} km^{-1}, respectively. Results of our study are in line with the findings in other watersheds elsewhere in Ethiopia. For instance, in Silti, farmers were challenged by the high labor demand of stone bunds, *Fanya juu* and soil bunds (Ali and Surur, 2012). Moreover, Tefera and Sterk (2010) also pointed out that high labor demand of the SWC structures did result in low construction by farmers in Fincha'a watershed. In both Bokole and Toni watersheds, focus group discussants agreed that the main causes of shortage of household labor for the construction of SWC structures encompass: i) presence of older aged people and children that cannot adequately involve in the labor-

Fig. 2. Typical SWC structures in two watersheds in Southwest Ethiopia; Stone bunds in Bokole watershed (left); Soil bunds in Toni watershed (right). Photo: Kebede Wolka.

Table 4
Perceived benefits, and challenges in implementing SWC structures in Bokole and Toni watersheds, Southwest Ethiopia.

Perception/observation on soil erosion, conservation structures and management		Bokole Watershed		Toni watershed	
		Adopters (%) (n = 73)	Non-adopters (%) (n = 39)	Adopters (%) (n = 52)	Non-adopters (%) (n = 37)
Perceived benefits of SWC structures	Reduce surface run-off	87.7	92.3	98.1	97.3
	Reduce soil loss	89.0	92.3	100	97.3
	Conserve soil moisture	74.0	71.8	98.1	64.9
	Reduce rock outcrop	53.4	48.7	0	0
	Maintain soil fertility	82.2	74.4	100	97.3
	Improve crop production	80.1	76.9	94.2	100
	Structures are durable if managed	68.5	48.7	80.8	59.5
Challenges in building SWC structures	Available labor not sufficient	89.0	82.1	71.7	54.1
	New skill demand	13.7	41.0	30.2	54.1
	Lack of awareness	11.0	33.3	41.5	54.1
	Lack of input	0	10.3	11.3	5.4
	Lack of material	4.1	2.6	3.8	10.8
	Shortage of incentive	0	0	0	8.1
Limitation of SWC structures	Require intensive labor	98.6	94.9	94.3	56.8
	Difficult to repair	93.2	97.4	92.5	56.8
	Require large volume of material	95.9	92.3	92.5	59.5
	Susceptible to damage when poorly used	65.8	51.3	35.8	10.8
	Compete cultivable space	89.0	82.1	73.6	27.0
Workability of SWC structures	Easy	19.2	0	5.1	0
	Moderate	35.6	5.8	10.3	6.9
	Difficult	45.2	94.2	84.6	93.1

intensive task of constructing SWC structures; ii) children going to school; and iii) lack of capital to hire labor. Thus, a larger family size (Table 2) does not directly mean more labor availability to engage in this labor-intensive business.

Compared to the adopters, a higher proportion of non-adopters in both watersheds perceived that building the SWC structures demands a technical skill for design and construction works (Table 4). They perceived that they have limitations on awareness and technical workability of the SWC structures as they did not practice it in their previous farming life. In addition, as explained by experts of agriculture and natural resource development, farmers initially believed that the government could systematically take their land after construction of the promoted SWC structures as it provided financial and material support for the work. That has affected their acceptance of SWC structures. Proper design and construction of each type of SWC structure requires a specific skill. The technical specifications of some SWC structures (e.g. determining foundation, depth and width of the structures) can easily be acquired by land users but adjusting graded and level lines (when needed) and spacing of the SWC structures demand technical skill and also use of instruments. As perceived by land users, the skill demand of the SWC structures can challenge the adoption rate. This urges local experts the need for arranging further awareness creation opportunity, technical support and field demonstration. This support need to capacitate and empower land users so that they can acquire the required skills. The existing educational level, where a higher proportion of the respondents are illiterate, may limit the speed of acquiring new knowledge and skill. Practically, introducing and scaling out the new SWC structures in intricate rural situations requires continued efforts.

Another perceived challenge by the farmers was that the SWC structures occupy a certain proportion of cultivable land as perceived by 89% of adopters in Bokole and 73.6% of adopters in Toni (Table 4). The SWC structures require cutting and filling of soil material, opening channels and heaping embankments, and installing strips of rocks that indeed occupy a certain area of the cultivable land. In both watersheds, the higher proportion of both adopter and non-adopter farmers possess farmland area of about 0.5 ha and below (Table 2). When compared to adopters, a higher proportion of non-adopter farmers in Bokole and Toni watersheds possess less farmland (Table 2) that might have discouraged the non-adopter farmers to implement the technology. In Toni watershed, experts of agriculture and natural resource development indicated that farmers complain about the cultivable space occupied by the structures, and thus the farmers prefer either not to construct the SWC structure or use wide spacing between the structures (if they adopted) as a solution. Other findings in different parts of Ethiopia including southern (Tadesse and Belay, 2004), western (Anley et al., 2007), northern (Tesfaye et al., 2014), eastern (Bekele and Drake, 2003), and central (Amsalu and De Graaff, 2007) revealed that smallholder farmers complained that constructing SWC structures occupies their cultivated land. In Bokole watershed, usually, the younger farmers have been more influenced by farmland shortage as they possess smaller land size which is less than the overall mean. Because the youth have inherited their lands from their parents as no land redistribution was carried out in the area after the 1973 change in government.

The need to maintain soil fertility, even though the land holding is small, can be argued. On the other hand, a return from the investment in SWC structures can take some time, often a few years (Tenge et al., 2005, 2007). Thus, for the rural poor in a developing country that having limited resource for current survival, it becomes difficult to envisage the long-time benefits by partially compromising the current harvest. Other studies in central highlands (Shiferaw and Holden, 1999), Fincha'a watershed in western highlands (Tefera and Sterk, 2010) and Farta woreda in northern highlands (Birhanu and Meseret, 2013) confirmed that when the short-term benefits obtained from the SWC structures were low the farmers lost interest in the construction of SWC structures. Tenge et al. (2004) also showed that lack of short-term benefits from SWC influenced its adoption in Tanzania.

3.4. Factors affecting adoption of SWC structures

The rate of scaling up of the SWC structures ensures the sustainability of the technology in the watersheds. On the other hand, in most farming practices of the rural poor, adoption and scaling up of new technologies is a slow process and requires a participatory approach (Okoba et al., 2007; Tenge et al., 2007). New technologies may take

Table 5
Factors influencing adoption and repairing of SWC structures in Bokole and Toni watersheds, Southwest Ethiopia.

Socio-economic characteristics	Adoption of SWC structures				Repairing SWC structures			
	Bokole (n = 73)		Toni (n = 52)		Bokole (n = 73)		Toni (n = 52)	
	X^2	p	X^2	p	X^2	p	X^2	p
Family size	0.885	0.845	1.865	0.636	0.907	0.91	1.527	0.76
Age of household head	3.854	0.292	3.358	0.348	0.955	0.891	3.298	0.376
Administrative responsibility in kebele	2.779	$^{-}$0.08**	0.474	0.446	0.013	0.639	1.246	0.299
Number of cattle owned	10.504	$^{-}$0.014*	2.389	0.499	2.797	0.45	2.046	0.587
Educational level	4.323	0.235	4.048	0.261	2.459	0.522	8.195	$^{-}$0.045*
Farmland area	6.479	0.166	1.627	0.960	11.64	$^{-}$0.03*	1.514	0.891
Frequency of development agent contact	1.575	0.692	4.665	0.336	5.04	0.163	3.088	0.618
Perception of soil erosion seriousness	2.501	0.476	4.746	0.205	3.86	0.302	2.546	0.715
Perceived workability of SWC structures	16.396	$^{+}$0.008*	0.474	0.446	0.329	1.0	0.014	0.701

* Significantly different at $p < 0.05$; ** significantly different at $p < 0.10$; $^{-}$ negatively influence; $^{+}$positively influence.

time until they are well tested and improved based on successes and failures (De Graaff et al., 2008). In line with this, in Bokole and Toni watersheds, the focus group discussants indicated that farmers were initially hesitant on intended interventions by expressing their feeling that the government may evict them from their land after building the SWC structures. This could be one of the reasons for non-adopters of SWC structures who are not building the SWC structures in their cultivated lands that are apparently susceptible to erosion.

In Bokole watershed, the number of cattle owned has significantly ($p < 0.05$) affected construction of the SWC structures (Table 5). Respondents possessing comparatively large number of cattle had less tendency of adopting the SWC structures. This could be because those households who have a large number of cattle have comparatively good resource options to depend on and thus less concentrate on crop production. Amsalu and De Graaff (2007), Tefera and Sterk (2010) and Tesfaye et al. (2014) also reported that farmers possessing a high number of cattle have resource options besides cropland and thus are less concerned about constructing and maintaining of the SWC structures for improving crop productivity. Furthermore, even though some farmers traditionally allot a small area of land for cattle grazing especially in cropping seasons, allocating sufficient private grazing land appears difficult for most farmers especially in the face of existing land shortage. During non-cropping seasons, cattle are allowed to free grazing on croplands and may damage the built structures, which negatively affects the interest of construction and repairing of the SWC structures. Thus, farmers possessing a higher number of cattle disregard construction of the SWC structures by anticipating repeated damage of the built SWC structures by cattle, and thus were not willing to construct. Tefera and Sterk (2010) also reported that free grazing negatively affected construction of the SWC structures.

In Bokole watershed, administrative responsibility in the kebele influenced construction of the SWC structures significantly ($p < 0.1$) and negatively (Table 5). This could be due to the fact that those people who are frequently engaged in such additional assignments could have limited time to manage labor-intensive farm activities such as SWC structures. Moreover, they may have alternative income sources from such activities and as a result are less concerned about their agricultural activities.

3.5. Repairing of SWC structures

In Bokole watershed, a higher proportion of adopters and non-adopters mentioned that SWC structures are susceptible to damage when poorly managed (Table 4). About 71% of respondents in Bokole watershed and 90% of respondents in Toni watershed perceived that free grazing damages the built SWC structures (Table 6). In both watersheds, the diminishing communal land for free grazing had aggravated damage of the SWC structures as cattle have been allowed to roam and graze on cultivated land in off seasons. This is because maize stalks and other crop residues are important sources of livestock feed.

In both Bokole and Toni watersheds, a great majority of respondents perceived that soil tillage activities in inter-bund areas can damage the structures (Table 6). In Ethiopia, tillage is widely undertaken using the traditional *Maresha* (a tillage tool pulled by two oxen). Similarly, in both watersheds, land tilling has been carried out by this traditional *Maresha* during which oxen trample and damage the structures. This type of tillage forms untilled land between two consecutive furrows. Thus, farmers have to deal with the unplowed strips by making the subsequent tillage operations perpendicular to the previous. The need for cross plowing rules out contour plowing, which is difficult to do in between consecutive SWC structures. This has contributed to the low adoption of widely promoted SWC structures in the Ethiopian highlands. The repeated and cross-plowing of inter-bund areas, especially closely cultivating to embankments of the SWC structures can gradually reduce their thickness and make the structures susceptible for further break down. It is due to land shortage that farmers cultivate plots close to the SWC structures and make the structures susceptible to damage. Compared to Bokole watershed where more HHs have stone bunds, a higher proportion of respondents in Toni watershed were challenged by this problem due to the nature of highly susceptible structures such as soil bunds and *Fanya juu*.

When compared to Toni watershed, a lower proportion of HHs in Bokole watershed perceived damage of the SWC structures by free grazing, overtopping surface runoff, and tillage activities (Table 6). This could be due to the difference in level of susceptibility of structures to damage. For instance, soil bunds and *Fanya juu* are easily broken whereas the stone bunds, which are common in Bokole watershed, tolerate. On the other hand, a higher proportion of respondents in Bokole watershed involved in repairing the structures whereas majority of HHs in Toni watershed ignore the damaged bunds and *Fanya juu*. This is because Bokole watershed is comparatively hilly and exposed to water erosion and attracted farmers' attention. Furthermore, lower and middle parts of Bokole watershed had experienced water stress due to drier climatic nature and thus farmers engaged in repairing the structures for moisture conservation. Even though farmers in Toni watershed perceived water erosion as a severe problem (Table 3) and highly appreciated the benefit of bunds and *Fanya juu* (Table 4), they poorly engaged in repairing the structure. This implies that the perceived severity of problems and observed benefits of conservation may not always lead to repairing of structures. The structures were majorly built through incentive-based scheme, which might also contributed to the low motivation of repairing.

4. Conclusion

The Omo Gibe basin has huge economic and environmental benefits

Table 6
Causes of damage and repairing of SWC structures in Bokole and Toni watersheds, Southwest, Ethiopia.

Repairing SWC structures		Bokole watershed Adopter (%) n = 73	Toni watershed Adopter (%) n = 52
Causes of damages of SWC structures	Free grazing by livestock	71.2	90.4
	Overtopping runoff	83.6	98.1
	Land tillage activities	52.1	80.8
Repair damaged structures	No	8.2	61.5
	Yes	91.8	38.5

for both Ethiopia and Kenya. The results of this study revealed that farmers clearly understood aggravated water erosion as a problem in both Toni and Bokole watersheds. Farmers were selective in accepting and implementing SWC structures depending on the local land characteristics. Hence, stone bunds were widely implemented in Bokole watershed where rock fragments are abundant and *Fanya juu* and soil bunds were widely practiced in Toni watershed where rock fragments are not available. In both watersheds, the respondents understood fundamental benefits of these SWC structures including reduced runoff and soil loss, maintained soil fertility, improved soil moisture, and increased crop yield. In this regard, the SWC structures were perceived to positively contribute to agricultural production. The scaling up and repairing activities of these beneficial SWC structures are impeded by their labor-intensive nature and competing for cultivable land area.

Factors influencing the adoption and repairing of the SWC structures are different between Bokole and Toni watersheds. In Bokole watershed, adoption of the SWC structures is negatively influenced by number of cattle owned, perceived workability of the structures, and assuming administrative responsibility in the kebele. The effort to sustain the built SWC structures is weak in Toni watershed as the practices of repairing the damaged SWC structures are insufficient. In Toni watershed, the education level of the head of HH negatively influenced the repairing of the SWC structures. In Bokole watershed, the farmland area affects farmers' effort of repairing the SWC structures negatively.

In general, the respondents' preferences of SWC structures, rate of adoption, willingness to repair and factors affecting adoption and repairing were different in Bokole watershed when compared with Toni watershed. This could imply that the determinant factors for adoption and sustainability of SWC structures could be different for different watersheds. The study again highlighted the site-specific influence of socio-economic and biophysical factors on adoption and repairing SWC structures. Thus, we conclude that effective implementation and sustainability of SWC structures in watershed areas should consider the biophysical factors, such as land characteristics, environmental conditions of the watershed, and the types of SWC structures. In addition, socio-economic factors like labor availability, land holding size, livestock possession and education level of HH leaders are important determinants for the adoption and maintenance of SWC structures. The development workers and planners should be flexible in considering a specific local level dynamism of these factors to increase the chance of sustaining SWC structures.

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