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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.