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Review

Conservation and production impacts of soil and water conservation practices under different socio-economic and biophysical setting: a review

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Abstract: In Ethiopia, the increase in land degradation mainly in the form of soil erosion necessitates implementation of soil and water conservation (SWC) practices. So far impact evaluation studies are scattered and not comprehensive. In this paper detailed quantitative review of impact of SWC practices under different climate and socio-economic setting were done on runoff, soil loss, siltation, soil fertility and crop yield. Up to 1980s, expert and government considered reduction of soil loss and runoff as big achievement. This was not in line with the interest of subsistence farmers who need short term benefit. The reduction of soil loss, runoff and siltation of reservoirs are positively acknowledged by majority researchers and have several beneficial effects: increase soil moisture content, groundwater recharge, increased in situ sediment deposition, making the hill slope suitable for agriculture and reduce siltation. Regarding production objective, SWC practices have mixed impact (positive and negative) on crop yield and soil fertility. In this review it was found that 62.5% of the reviewed materials revealed that SWC measures have positive impact on soil fertility either in increasing or maintaining. In contrast, 25% showed SWC treated areas had lower soil fertility than untreated and 12.5% showed no significant change in soil fertility. In summary, the impact of SWC practices especially on soil fertility and crop yield varies depending on soil erosion degree before SWC implemented, design of SWC measures, crops, plows, socio-economic, soils types and climate mainly rainfall. The review in detail discussed why SWC practices have variation in impact on soil fertility and crop yield. Finally SWC practices are an action of no option for sustainable development and food security under current soil erosion and climate change.

Keywords: *conservation, physical soil and water conservation, production, runoff, soil erosion*

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Introduction

Sustainable livelihood and increased food production in agriculture-based developing countries require the availability of sufficient water and fertile land among others (Tesfaye, 2011). However, land degradation, a major global agenda, put its adverse impact on environment, food security, climate change adaptation and mitigation and the quality of life (Slegers, 2008). The situation is severe in the Ethiopian where land degradation has rendered vast areas of fertile lands unproductive (Gilligan and Hoddinott, 2007; Kassie et al., 2010) and it has been going on for centuries (Hurni et al., 2010). One of the major causes of the downfall of many flourishing empires, including ancient Axumite Kingdom, civilizations of Lalibela in the 14th century and Gondar in the 17th century was land degradation. Although estimates of the extent and rate of soil erosion and associated nutrient losses lack consistency, several studies reveal the severity of the problem. The highest rate of soil loss occurs from cultivated lands, ranging from 50 t/ha/yr (Adimassu et al., 2012) to 179 t/ha/yr (Shiferaw and Holden, 1999). Most cultivated lands in the hills and mountains of the country have suffered from loss of topsoil, leaving bare stones. Gullies are observed everywhere, and rivers are reddish brown during the main rain season due to soil erosion from their catchments. Soil erosion is major concern for Ethiopia, where agriculture accounts for 47% of GDP, employer to nearly 85% of the population, especially of the poorer and less educated segments of the population, account for 84% of export revenues and almost all of national food needs (World Bank, 2011).

To tackle land degradations impact on food security and environment, various resource conservation programs and schemes are being implemented. For the first time, land degradation mainly in the form of soil erosion has been recognized since 1973/74, subsequent to the devastating famine of the time (Dejene, 2003; Bewket, 2007). For about four decades, afforestation and soil conservation activities were massively implemented in drought-affected areas of Ethiopia for two reasons. 1) Relief food and oil arrived into the country; dictate the decision to concentrate on the drought-prone areas. 2) The old dichotomy of the country into two broad categories, i.e., “high potential” and “low potential” areas. It was thought that land degradation is not a problem in the so-called “high potential” areas. As a result, the focus of the government and other non-state actors in halting land degradation in a relatively high rainfall area of the country was very limited for decades. The second phase is the recent, ongoing 30 day national wide community based participatory integrated watershed management campaign which was started in 2010. The motive of the second phase was the growing awareness of land degradation and its impact agriculture, climate change, siltation of hydropower dams and lessons learned from Ethiopia’s Tigray region who won Gold in the 2017 future policy award for world’s best land restoration policies and practices organized by the World Future Council and the United Nations Convention to Combat Desertification (UNCCD). Furthermore, it is in line with Ethiopia’s Climate-Resilient Green Economy strategy (CRGE) launched in 2011.

The success of SWC measures could be the result of long-time experience passed through modification of types of SWC, approaches, institution and research results. In fact, the impact of SWC practices over different time periods have not been consistent between crops, plows, socio-economic, soils and climate in different parts of the world (Ahuja et al., 2006), implying impact evaluation cannot be replicable. Sometimes implemented SWC programs had negative impact, because of poor implementation of good technologies (Merrey and Gebreselassie, 2011). Scholars recommended the need for selection and implementation of technologies that are appropriate to specific soils and ecoregions (Girmay et al., 2008). In Ethiopia, despite a strong effort from government, community and donors to tackle land degradation there are no comprehensive study that evaluates SWC measures from on-site and off-site point of view. Most common areas of study are: crop yield, soil fertility, soil loss and runoff. Especially, recent studies evaluate SWC measures impact largely in view of soil fertility and crop yield. Moreover, individual studies are fragmented and were not under different socio-economic and biophysical setting. Therefore, this paper reviews the impact of SWC technologies comprehensively (on-site and off-site) including the magnitude of the contribution of the SWC measures on soil fertility, crop yield, runoff and soil loss and off-site impact mainly siltation of reservoirs under different socio-economic and biophysical setting, outlines the technologies, socio-economic, climate, institutions and practices that affect the outcomes of SWC technologies.

Experience of Natural Resources Management in Ethiopia

Indigenous land management is the result of a gradual learning process and emerge from a knowledge base accumulated by rural people by observation, experimentation, and a process of handing down through generation people’s experience and wisdom (Kruger et al., 1996). Farmers in Ethiopia have a wide variety of indigenous land management techniques that they have been employing for generations to survive under land degradation though some of them are in danger of being lost (Desalegn, 2001). Mulat (2013) described the Konso cultural landscape is characterized by extensive dry stone terraces which witnesses hundreds of years of persistent of human struggle to harness the hard, dry and rocky environment. The terrace practices are registered by the United Nations Educational, Scientific and Cultural Organization (UNESCO) as a world heritage. Some rudimentary and poorly established terraces and lynchets depicted on older aerial photographs and physical remnants are observed in different parts of the northern highlands (Nyssen et al., 2007).

However, institutionalized natural resources conservation was for the first time recognized and got policy attention since 1974, subsequent to the devastating famine of that time. Prior to 1974, the wrong policies of the feudal regime did not pay attention to smallholder farmers. Although almost all the population rely on small-scale agriculture, the policy of the regime focus on industrial development. According to Dejene (1990), the first two five year plans (1957-62 and 1962-1967) gave priority to large-scale commercial farms and exportable crops. The third five-year plan (1968-1973) put much emphasis on high input package programs to be implemented in few high potential agro-ecological areas where quick return was expected (Dejene, 1990). Small farmers that cultivate almost all-agricultural land and who are complained to be agents of soil degradation, failed to get policy attention. Therefore, policy attention towards industry combined with complex system of land tenure hindered the effort to conserve land (Campbell, 1991). In 1974, with a significant quantity of relief food arriving into the country, afforestation and soil conservation activities was massively implemented in drought-affected areas of the country in the form of food for work (Wogayehu and Lars, 2003). However, evaluation of soil conservation and afforestation revealed that most conservation structures were not maintained and they have been ploughed. Closed areas have been encroached and returned to their original condition. The salient causes accountable to the damages were: wrongly applied techniques, inappropriate technology preferences, insufficient research support, low public awareness and low technical capabilities of field technicians.

Research, Training and Extension in Soil and Water Conservation

For the first time, a research set up called the 'Soil Conservation Research Project' (SCRP) was established in 1981 with objectives to monitor soil erosion damage, develop viable models of soil, runoff and productivity loss, and develop ecologically sound, economically viable, and socially acceptable conservation measures and approaches. The Ethiopian Institute of Agricultural Research (the then Ethiopian Agricultural Research Organization, EARO) established in 1940 concentrated mainly on soil fertility studies for crop production. Government agricultural offices were also not emphasized on land resources. The offices were accountable mostly to livestock and crop aspect. The soil and water conservation technologies introduced by both government extension system and NGOs working at grassroots level is predominantly biased to standard structural SWC technologies. The technologies are biased towards reducing soil loss rather than enhancing agricultural production. Extension agents were also not in a position to include indigenous knowledge into the package of practices (Desalegn, 2001).

In Ethiopia, training in higher institutions related to natural resources management was young. For long time, courses related to land resources (vegetation/forests, soils and water) offered in universities were consolidated into soil science disciplines where the emphasis is more in managing the soils fertility for crop production. In some institutions such courses are not even considered as requirement for earth science students. Only, Asmara university offered soil and water conservation as a discipline in the late 1980s as a degree program. Eventually, when the College of Dryland Agriculture and Natural Resources was established in Mekelle University, the Department of soil and water conservation was maintained for offering the training in 1991. Except Mekele University, first generation universities (Jimma, Addis Ababa, Hawasa, Haramaya, Gonder and Bahir Dar universities) had not emphasized on natural resources management training for decades. For example, Jimma University as a college of agriculture was founded 70 years ago, and the university started to offer natural resources management training recently in 2004.

Recently, the Ethiopian government highly emphasized on natural resources management. By late 1990, watershed development was considered the focal point for rural development and poverty alleviation. PASDEP (2006) proposes various interventions in natural resource management including sustainable land use and forests development, and soil and water conservation. The Agricultural Sector Policy (MoARD, 2010) highlights the need for rehabilitating degraded areas and preventing further deterioration through better soil fertility management, introduction of soil conservation measures, reforestation, and appropriate conservation agriculture methods. The CRGE (2011) recommends the introduction of sustainable land management practices such as agronomic practices, effective tillage and residue management, terracing, water harvesting techniques and agro-forestry to prevent soil erosion and degradation.

The GTP I (2010) and GTP II (2015) also propose implementation of soil and water conservation using organized community participation. Furthermore, water sector policy MoWRE (1999), environmental policy (EPA, 2011), rural development policy and strategy, food security strategy and forest conservation and development policy all are in favour of natural resources management. Consequently, a number of first and second generation universities are offering training in the area of natural resources management.

Desired of Impact of Soil and Water Conservation Measures

During the first generation of institutionalized soil and water conservation in 1970s there was quit misunderstanding about the role SWC. For the experts or technicians, reduction of soil loss and runoff per hectare was considered as big achievement. During that time, the main emphasis on soil and water conservation was on physical soil and water conservation measures to reduce soil loss and run-off. Biological and indigenous SWC measures were not emphasized. This is really a failure start, especially in humid and sub-humid areas that have a higher potential for biological and agronomic SWC measures. In fact the overlooked biological SWC measures are less costly, less maintenance cost, recognizable production function for subsistence farmers, improves infiltration, fertility and soil organic matter.

On farmers' side, they need tangible yield increment benefits within short period of time. In contrary, mechanical SWC leads to a reduction in crop yield for the first few years due to the farmland taken by the physical conservation structures and the disturbance of the most fertile topsoil during the construction of the physical soil conservation measures (Bedadi, 1999). This difference between expert and farmers and other socio-economic and technical challenges resulted in less adoption and destruction of farmland terraces in Ethiopia during the first generation of SWC. Later on, the resistance from farmer's side was got attention. Today, the desired impacts of soil and water conservation are well understood. Production should increase, and soil loss should decrease. Runoff, in contrast, is a more complicated issue and needs to be evaluated with care considering climate, particularly rainfall.

Performance of SWC Measures

Impact on soil loss and runoff

SWC structures serve as a reservoir system when installed along the contour as they trap runoff and sediment. In experimental plot, Gebeyehu et al. (2013) reported that after each storm, runoff pounded behind SWC structures, leading to rapidly vegetation recover at the onset of the rainy season, forming patchy vegetation islands around SWC structures while all of the runoff from control plots ended up in the collector trenches. The reduction in runoff and soil loss have several beneficial effects: increased soil moisture content (Mesfin 2004 and Mihrete 2014); groundwater recharge (ICRISAT, 2007; Negusse et al., 2013) soil-loss reduction (Herweg and Ludi, 1999; Gebremichael et al., 2005; Gebeyehu et al., 2013); increased in situ sediment deposition, making the hill slope suitable for agriculture due to progressive terrace development (Haregeweyn et al., 2006; Nyssen et al., 2007), and reduced siltation of natural and artificial reservoirs (Haregeweyn et al., 2006; Tamene et al., 2005 and Emiru, 2009). The role of SWC for climate change adaptation and mitigation was also widely reported (Smith et al., 2008; Lal, 2004).

In Ethiopia, recent studies are scant on the performance of SWC on soil loss and runoff. Almost all studies are on impact of SWC on selected soil physical and chemical properties and to some extent on crop yield. This could be due to the difficult and the high cost of studying soil loss and runoff. It could be also related to the seasonality of soil loss and run off study. Only in the early 1980s notable impact of SWC measures on soil loss and runoff was studied by Soil Conservation Research Programme (SCRP) established by the government of Ethiopia and Switzerland. Table 1 below shows the impact of SWC measures on soil loss, runoff.

The study was under different agro-climate, topography, and soil types and data were collected for 5 consecutive years under farmer's condition. In general, the result revealed the positive impact of SWC, in reducing soil loss and runoff although the magnitude of reduction was different probably depending on erosion history of the experimental plot, slope and climate conditions of the sites. As expected soil and runoff reduction of level structures were higher than graded structures. This explains that, from environmental or ecological point of view level structures are interesting. However from production point of view it should be evaluated carefully considering water logging and moisture conservation aspects. There is large temporal and spatial rainfall variability in runoff and soil loss, even at the catchment scale (Taye et al., 2013). This clearly indicates that, study of SWC measures on soil loss and runoff need time series data and never completed in one year or season. For example in Table 1, it can be seen that large year to year variation of annual soil loss and runoff under the same experimental plot. Despite this fact, most study use one season soil loss and runoff data to evaluate the effectiveness of SWC ((Taye et al., 2013).

Table 1. Effect of SWC practices on soil loss and runoff under different climate condition. Source: adapted from Herweg and Ludi (1999)

Research site/area	**Annual rainfall (mm)**	**Without SWC**		**With Physical SWC**			
		Annual Runoff (mm) mean (range)	**Soil loss (t/ha) mean (range)**	**Mean annual runoff (mm)**	**Mean % of annual runoff reduced**	**Mean soil loss (t/ha)**	**Mean % of annual soil loss reduced**
Afdeyu	382	162 (34–359)	42 (3–114)	75*	-54*	11*	-74*
Hunde Lafto	935	12 (1–18)	7 (0–16)	0.65*, 18**	-95*, +50**	0.0*, 2.8**	100*, -60**
Maybar	1211	24 (17–30)	2 (1–4)	16.5*, 32**	-31*, +33**	0.85*, 2.6**	-58*,+ 30**
Andit Tid	1358	354(183–688)	48 (2–140)	163*, 285**	-54*, -20**	6.5*, 24**	86*, 50**
Gununo	1314	131 (50–262)	11 (1–22)	15*, 50**	-89*, -62**	0.25*, 1**	98*, 90**
Dizi	1512	45 (9–139)	5 (0–25)	24*, 23**	-47*, -49**	0.5*, 0.6**	90*, 88**
Anjeni 28%	1690	487 (359–620)	110 (59–167)	328**	-33**	37**,	67**
Anjeni 12%	1690	482 (365–645)	90 (17–176)	265**	-45**	26**	71**

Note: * = refers to result of level structures; ** = refers to result of graded structures

This can either overestimate or underestimate the impact of SWC measures on soil loss and runoff depending on the rainfall of the year/season during which data collected-**.** Additionally, newly built physical SWC measures are more effective in reducing runoff and soil loss (Desta et al., 2005; Nyssen et al., 2007). The rate of sediment deposition above stone bunds decreases with age of the bund owing to the filling up of the depression, formation of level land gradually and bunds may be destroyed with time. This suggests the need to describe the status of SWC measures under study in terms of age, maintenance and design. Management practice such as increasing the height of stone bunds can also influence stone bund effectiveness in trapping sediment (Nyssen, et al., 2007).

In addition to the above data in Table 1, Nyssen et al. (2010) and Hurni et al. (2005) at catchment-scale showed that 81% and 50% reduction of runoff coefficient (RC) respectively after implementing SWC structures compared to the condition before catchment management. Dano and Siapno (1992) found a 61% runoff reduction relative to a control plot for stone bunds in humid areas of the Philippines. Similar to runoff, finding revealed that, SWC structures significantly reduce soil regardless of land use and slope gradient. Gebeyehu et al. (2013) showed that installation of stone bunds reduces soil loss by 63% in rangeland and 40% in cropland. Similarly, Desta et al. (2005) found a 68% soil-loss reduction due to the implementation of stone bunds on cropland at farmer's plots in Tigray.

In general, despite the mixed outcome of SWC on crop yield and soil fertility, majority of studies reported SWC measures have positive role in reducing soil loss and runoff at plot and catchment scale.

Impact of SWC on some soil physico-chemical properties

Young (1989) defined soil conservation as a combination of controlling erosion and maintaining soil fertility. Recognizing this fact, the Ethiopian government has developed a number of policies and strategies that support SWC measures in a holistic and landscape-wide approaches that go beyond resource conservation towards improved livelihood of the rural people that constitute over 85% of the population. In Ethiopia, the main objectives of SWC measures are improvement and/or maintenance of soil fertility and moisture and thereby crop yield improvement. Soil physical and chemical properties that are usually affected by SWC measures are Soil Organic Matter (SOM), Total Nitrogen (Nt), soil moisture content (SMC), Cation Exchange Capacity (CEC) and available phosphorus (avP). Although the central objective of SWC is soil fertility and then crop yield, especially in developing countries like Ethiopia, the fact on the ground is not always true and is not in accordance with expectation in many cases. In this article it was found that 62.5% of the reviewed materials revealed that SWC conservation measures have a positive impact on soil fertility either in increasing or maintaining soil fertility (Table 2). In contrast, 25% showed SWC measures treated plots or watershed had lower soil fertility than untreated and 12.5% showed no significant change in soil fertility. In general, comparing SWC treat and untreated plots or watershed, the majority reported SWC treated areas have better soil fertility than untreated area.

Table 2. Effect of SWC measures on soil physical and chemical properties

Author	Annual Rainfall (mm)	Age of SWC	Soil parameters					
			OM (%)	Nt (%)	avP ppm	SMC (%)	Ex. Bases	CEC
Damene, 2012	1211	25 years	-0.69	-	-5.16	-	-16.5	-
Getnet, 2014	1250	5 years	+0.27	+0.04	+3.4	+4	-	-
Tugizimana, 2011	1600	-	+1.2	-	-	3.4		+7
Ayalew, 2011	2000	3 years	-0.62	-0.03	+1.73	+11	+0.55	-2
Hailu et al., 2012	1600	5 years	+0.26	+0.04	-1.54	-		+1.26
Hailu et al., 2012	1600	10 years	+0.22	+0.06	+3.33	-	-	-0.91
Chala et al., 2016	1250	6 years	+0.55	+0.07	-	+2	-	+8
Masresha, 2014	1300	6 years	-0.54	-0.03	-2	-	-	-
Bekele et al., 2016	1200	12 years	+1.88	+0.16	+4	-	+3.77	+7

An important to discuss is how SWC especially physical measures improve soil fertility? The reasons are either one or combination of the following: 1) majority of scholars justified higher soil fertility in treated area could be due to reduction of soil loss and thereby soil fertility. However, this cannot be justified as soil fertility improved, rather it can be explained as soil fertility maintained as defined by (Young 1989). Because, the total nutrient stock or balance in the plots or watershed is the same except spatial variability. For instance, erosion causes significant redistribution of soil materials and fertility within the space between the structures. Soil materials eroded from upper inter-structural position are deposited at the lower inter-structural position of conservation structures. Soils at the deposition sites experience a net gain of soil and fertility while those in the upper undergo net losses (Damene, 2012; Getnet, 2014; Vancampenhout et al., 2006). According to Getnet (2014), gradual bench terrace formation might reduce topsoil fertility gradients within a terrace, although it will not avoid soil depth variation. For those finding that soils fertility of SWC treated plots or watershed is lower than untreated, no justification except prior deference between the treated and untreated. 2) other scholars argued improvement of soil fertility in SWC intervention is due to agronomic and vegetative SWC measures and additional intervention beyond soil and water conservation in the form of soil fertility management and management measures like land use change. The aim of vegetative measures is to maintain a high vegetative cover, which serves two purposes, production and protection. The roots of agronomic and vegetative SWC measures improve soil structure, and thus aeration, infiltration and biological activity in the soil. Plant residues build up soil nutrients and soil organic matter and thus improve stability of the soil structure and aggregates.

Impact of SWC on crop yield

Land degradation in the form of soil erosion has significant negative consequence on sustainable development through its on-site and off-site impact. In Ethiopia, one of the major causes of the downfall of many flourishing empires, including ancient Axumite Kingdom, civilizations of Lalibela in the 14th century and Gondar in the 17th century was land degradation. Consequently, SWC measures are implemented with functional principles of controlling erosion, improving infiltration and maintaining or improving soil fertility and thereby increase yield Young (1989). Despite these objectives, performance evaluation of SWC on crop yield and soil fertility showed quit mixed outcomes. Majority of studies reported positive impact of soil and water conservation measures on soil physical and chemical properties and crop yields (Mesfin, 2004; Mihrete, 2014 and Million, 2003). Few studies reported negative impacts of SWC (Kassie and Holden, 2005). Such mixed outcome is a source of confusion and affected the commitment of the wider community, researcher, policy makers and practitioners to promote SWC measures.

Because of the wide variations in topographical, pedological and climatic conditions in the highlands, yield increases that may result from soil fertility and moisture conservation may vary greatly. For example, Hurni (1989) points out that in the steep slopes of Jinbar valley in the Simen Mountains, a yield increase of up to 50% can be obtained following construction of bunds and terracing. In contrast, Kassie and Holden (2005) found that physical conservation measures resulted in lower yield in a high-rainfall area of Ethiopian highlands, compared to plots without conservation measures. However, their work did not compare yield effects of conservation measures in low- versus high-rainfall areas. Moreover, their study did not considered production risk without soil and water conservation. In similar to Kassie and Holden (2005), Sutcliffe (1993) concluded that physical soil conservation activities are justifiable in moisture-stressed areas of the Ethiopian highlands, where moisture conservation plays an important role in increasing yield. Similarly, Kassa et al. (2013) reported estimated performances of the SWC measures show considerable variability by agro-ecological type. Contrary to Sutcliffe (1993) and Kassa et al. (2013), many reported the positive impact of SWC on crop yield in high rainfall area (Herweg and Ludi, 1999). This explains the issue seems not only climate mainly in the form of rainfall. Thus, how SWC measures designed, under what slope, soil erosion degree and socio-economic conditions SWC measures implemented matters and should be explained in detail. Logically, what makes SWC measures more impart in low rainfall area than high rainfall area is their double benefit: soil fertility and moisture improvement provided that they are well designed and properly managed. In high rainfall area, soil moisture improvement role of SWC measures are not much important.

Reasonably, SWC measures are expected to reduce crop yield for the first few years due to the farmland taken by the conservation structures and the disturbance of the most fertile topsoil during the construction of the mechanical soil conservation measures (Bedadi, 1999). In contrast to this fact, Abay (2011), reported yield was increased by 22 % on some farms and 15 fold on other farms within one year of bund/fanyajuuconstruction and by >50 % after 3 years with similar farming practices. The work of Abay could be true if and only if intensive inputs like improved variety, fertilizers and other management activities were done with SWC measures. Otherwise, for most soil and water conservation technologies, there is a time-lag between their initial investment and felt impacts or productivity gains. Farmers reported that on an average they had to wait for 3 years to see the effects of stone bunds, stone lines and wood barriers on productivity gains, whereas for technologies such as vegetative bands, living hedges and small dikes, they had to wait only for a year.

Table 3. Effect of SWC practices on yield of crops under different climate condition

Authors	**Annual rainfall (mm)**	**Age of SWC in years**	**Mean yield increase (%)**
Mekonen et al., 2011	700	13	25%
Kasa et al., 2013	900	6	8.3
Herweg and Ludi, 1999	1211	4	-25%
Herweg and Ludi, 1999	1314	5	11%
Alemayehu et al., 2006	700	Indigenous SWC	190%
Ayalew, 2011	2000	4	22-50%
Olarinde et al., 2011	SSA		17-24%
Getnet, 2014	1250	5	+30%
Vancampenhout et al., 2006	600	12	+7%
Hadush, 2014	750	15	92%
Nyssen et al., 2007	769	3-21	12%

Note: * = result of level structures; ** = refers to result of graded structures

Impact of watershed management on siltation

Soil erosion and sedimentation are natural phenomena involved in landscape formation (Ndorimana et al., 2005). For decades, the off-site impact of land degradation mainly in the form of soil erosion is widely reported and even more negative impact on the economy than on-site impact, especially in developed countries. Notable off-site impacts are siltation, eutrophication, water yield and flooding and damage on infrastructures. Reservoir sedimentation has tremendous economic and environmental impacts. Some of the experienced impacts include Consequence of storage loss on production loss, downstream effects of reservoirs on the river bed, reduction in efficiency of power generation due to sedimentation and contamination due to sediment (Annadale, 1987). Between 1950 and 1970, big irrigation scheme and hydropower dams were constructed in Asia, Africa and Latin America to promote agricultural development and economic growth while ensuring water and electricity supply faced siltation problem. It is estimated that 1.5 billion Mg of sediment are deposited each year in the USA reservoirs (Brady and Weil, 2002). In Australia, for major dams constructed for the purpose of domestic water supply, agriculture and mining were completely silted in 25 years. According to (Shahin, 1993), the Egyptian aswanhigh dam lifespan is only half of the original design life due to high inflow of sediment from Ethiopian highland.

In Ethiopia, the problem of siltation is even more serious than the other parts of the world owing to high intensity of rainfall, rugged topography and where more than 85% of the population depends on agricultural activates for their livelihood. For instance, investigation on 50 micro dams constructed for irrigation scheme in Tigray region showed that the area-specific sediment yield of the reservoirs ranged between 345 to 4935 t/km/year with a mean of 1900 t/km/ year, the figure higher than global and Africa average of about 1500 and 1000 t/km/year. Many dams constructed to store water for irrigation and drinking were being silted up while under construction (Amare 2005). Serious sedimentation is in Borkena dam, in North Ethiopia where the dead storage volume of the reservoir completely silted before construction ended (Haregeweny et al., 2006). Elias (2003) reported an earth dam in the headwaters of Modjo river was completely filled with 96000 m^3 of silt only two years after construction. Nationally investment on hydroelectric dams in Ethiopia is mainly in Omo-Gilgle basin. Although no sufficient research on the issues, emerging evidenced depicted that the sustainability of Gilgel Gibe dams was under questions. For instance, Devi et al. (2007) reported that Gilgel Gibe river alone contribute sediment load of 277,437 t/year and the total sediment load of 4.50×10^7 t/year to Gilgel Gibe I and this amount could cover 3.75×10^7 m^3/year of the dam volume. The authors concluded that Gilgel Gibe I dam would be completely filled up in 24 years whereas it was planned to serve for 70 years. The Soil and Water Assessment Tool (SWAT) model by Demissi et al. (2013) similarly confirmed a drastic increase in sediment flux to Gilgel Gibe dam I if business as usual continued.

Photo 1. Reddish brown water due to high level of sediment flowing to Gilgel Gibe dam I

Watershed management as a measure to reduce siltation of reservoirs were advocated by the Bretton wood institutions and United Nations (UN) after the Second World War when big irrigation scheme and hydropower dams were constructed in Asia, Africa and Latin America to promote agricultural development and economic growth. Watershed management means putting in place systems that ensure land resources are preserved, conserved and exploited sustainably now and for future generations. Integrated watershed management encompasses implementation of many physical and biological activities such as physical soil and water conservation, crop management, soil management, vegetation/forest management. German et al. (2007) emphasized that integration in watershed management have to include integration of disciplines (technical, social and institutional dimensions) and objectives (conservation, food security and income generation).

Researchers from all over the world reported implementation of integrated watershed management has reduced soil erosion and subsequent sedimentation. To reduce sediments from entering Angereb dam, watershed management such as avoiding cultivation of steep slopes and reserving buffer zones have been recommended as measures (Amare, 2005). Tamene et al. (2005) recommended that to tackle the on and off-site erosion threats in Tigray region, there is an urgent need for improved watershed-based erosion control and sediment management strategies. Emiru (2009) recommended that watershed management measures should be taken to sustain river flow during the dry periods; reduce surface runoff and sediment load during the rainy season; and overall increase groundwater recharge. In Ethiopia's Tigray region, in recognition of the sedimentation threat to irrigation reservoirs various soil and water conservation were widely implemented. For instance, Haregeweyn et al. (2006) measured thickness of annual sedimentation rate in Gereb Segen reservoir before and after soil conservation practices were initiated in the watershed and obtained observable decrease of sedimentation. In the upstream watershed of a reservoir, three basic patterns of soil conservation measures are commonly taken to reduce sediment load entering reservoir: structural measures, vegetative measures, and operational measures (Morris and Fan, 1998). To conclude, in today's paradigm shift in watershed management (from technocratic to social consideration, sectoral to integration of sectors and multidisciplinary, from conservation focused to production and conservation) integrated watershed management seems best solution for sustainable development, climate change adaptation and mitigation and dams to serve their lifespan.

Why SWC Measures Resulted in Mixed Outcomes on Soil Fertility and Crop Yield?

Methods of study

Different authors use different methods to investigate the impact of SWC on crop and soil fertility, soil loss and runoff. It is expected that on the same plot of land, different methods of assessment of impact of soil and water conservation (SWC) yielded different outcome finally. At the same time, it is understandable that, quantifying the effects of soil erosion and soil and water conservation on soil and crop yield is a complex task. It involves the assessment of a series of interactions among soil properties, crop characteristics, land management, socio-economic, and the prevailing climate. Furthermore, SWC impact evaluation need time series data and never completed in one year or season. Especially what makes evaluation of SWC performance on crop and soil properties challenging is the absence of baseline data before implementing SWC practices especially in developing countries. In general, impact evaluations of SWC practices suffered from a number of methodological problems that may have led to under- or over-estimation of the productivity impacts of the SWC technologies

For example, most researchers studied the impact of SWC at watershed scale in which conserved and non conserved watershed adjacent to each other were compared to see the effect of SWC on soil loss, fertility and crop yield (Solomon, 2016; Biele, 2014; Alemayehu et al., 2006; Worku et al., 2012; Mihrete, 2014). This method seems to have a potential error to give clear picture of SWC impact. Most of them assume conserved and non-conserved adjacent watershed have similar in topography, soil and so forth. However, it is less likely that conserved and non-conserved adjacent watershed to have the same soil, slope, erosion history to say the difference between them in soil properties and crop yield is due to SWC implementation. For example, (Masresha, 2014), reported the non-conserved fields had significantly higher OM and TN compared to the conserved cultivated lands. Such difference can be due to prior differences of the lands at the start of the treatments, since areas already seriously affected are chosen first for conservation. Other methodological error is that, not to accounted land loss by physical SWC practices which ranges from 8 to 15%. Vancampenhout et al. (2006), Nyangena and Köhlin (2008), Alemayehu et al. (2006), Hailu et al. (2012) and Damene, (2012) classify watershed in to upper and lower and to different slope class and fail to consider individual farm variability. In this regard Abay (2011) reported increase of crop yield due to SWC practices differs from farmer to farmer as the management of soil is different among different farmers. Shimeles (2012) also observed terrace maintenance was based on individual interests, which meant differences on terraces that had however been constructed at the same time in a watershed.

Some studies use experimental setup of conserved and non-conserved plots (Bedadi, 1999; Tadele et al., 2011) to monitor change due to SWC. This method seems reasonable except it take long time as the response of mechanical SWC structures take long time to respond to soil fertility and crop yield. Other studies use baseline data of soil and crop yield before implementation of SWC (Shimeles, 2012; Tugizimana, 2011). This method needs careful monitoring and applicable under experimental plot to be sure that all changes in soil fertility and crop yield are due to SWC practices. In impact evaluation process, the main challenging is assuring the certainty of the change on the outcome is only from the intervention of program, not from other factor. Few studies use the central part of the inter-terrace sample as the best estimate of the situation before implementation of the structures (Dercon, 2001; Dercon et al., 2006 and Vancampenhout, 2006).

Differently, people from social science use different economic model to predict and assesses the impact of soil and water conservation (Gebremedhin and Swinton, 2005; Kassie et al., 2007). Some researcher evaluates impact of SWC practices based on farmers' perception (Wolka et al., 2013). Amdemariam et al. (2011) collected soil samples at deposition zone to evaluate effect of soil and water conservation practices on selected soil physical and chemical properties and barley yield which certainly overestimate the impact. In summary this review suggests the need to standardize and produce guideless for evaluation of SWC performance.

Difference in agro-climate

It is expected that different technology respond differently under different socio-economic and biophysical conditions. The fundamental objectives of soil and water conservations practices are reducing runoff and soil erosion, and thereby improving basin soil moisture, maintaining and/or improving soil fertility and thereby improving or maintaining agricultural production (Nyssen et al., 2006; Vancampenhout et al., 2006). In spite of this fact, it is not uncommon to see mixed outcome of SWC practices especially on crop yield and soil fertility. The soil conservation practices, when evaluated separately using different parameters showed a variation in their performance. For example, almost all studies revealed the positive impact of soil and water conservation practices on soil loss and runoff. However, there are quite mixed outcome regarding crop yield improvement of soil and water conservation practices. Such mixed outcomes are more pronounced in high rainfall areas than in low rainfall areas. Kassie et al. (2008) argued that physical SWC practices did not have a positive impact but reduced yield in the high-rainfall areas of the Ethiopian compared with non-conserved plots. Kato et al. (2011) concluded stone bunds, soil bunds, grass strips, waterways, trees, and contours have robust and positive impacts on crop yield in low-rainfall areas (both the instrumental variable GMM and OLS estimations), while only waterways and trees have robust positive impacts in high-rainfall areas. Similarly, Masresha (2014) and Kassie et al. (2008) reported negative impact of SWC practices under high rainfall conditions. In contrast, other reported the positive impact of SWC practices on crop in high rainfall area (Alemayehu et al., 2006; Ayalew, 2011; Amdemariam et al., 2011; Wolka et al., 2013). In general, from previous studies, it can be summarized that SWC is more important in low rainfall area than high rainfall regions. The justification forwarded was moisture conservation benefits of the technology are more beneficial in drier areas. SWC can improve moisture retention during low-rainfall periods and thereby reduce moisture stress and enhance plant growth (Hengsdijk et al., 2005). The negative impact of SWC on crop in humid areas was partly associated to waterlogging (Herweg and Ludi, 1999). The less significant and even sometimes negative impacts of SWC practices in high rainfall regions seem due to lack of customized SWC practices and wrong design of the technologies for the agro-climate (Nyangena and Köhlin, 2008).

Rainfall variability

Year to year rainfall variability is quite common in sub-Saharan Africa (SSA). Hence, it is not arguable that year to year rainfall variability complicated evaluation of SWC on crop yield. For low rainfall areas, during low rainfall season difference between control and conservation could be high, which is due to moisture conservation impacts of most SWC practices. Whereas in high rainfall season the difference could be minimized since, only the effect of soil fertility play role on yield of crop. Hengsdijk et al. (2005) discussed conservation can improve moisture retention during low-rainfall periods and thereby reduce moisture stress and enhance plant growth. This justifies the need for time series data to accurately quantify the impact of SWC practices on crop yield.

Response time of SWC practices and management

The impacts of the physical soil and water conservation practices can be classified into short- and long-term effects based on the time needed to become effective (Bosshart, 1997). According to Bosshart (1997), the short-term effects of stone bunds are the reduction of slope length and the creation of small retention basins for runoff and sediment. These effects appear immediately after the construction of the stone bunds. Reversely, impact on soil fertility and crop yield build gradually and are a long-term effect. The line of arguments is how different authors practically understand and evaluate the performance of SWC practices. Many researchers never mentions details about SWC practices they studied about their age, maintenance, their technical design, erosion history of the field before implementation of SWC practices which all have significant impact on the performance of SWC practices. Many said nothing about maintenance of SWC in their study area (Hailu et al., 2012; Mihrete, 2014; Challa et al., 2016) and age of SWC practices (Alemayehu et al., 2006). Management practice such as increasing the height of bunds can influence bund effectiveness (Nyssen et al., 2007). This implies that simply long year constructed SWC practices alone might not have a more positive impact than new SWC practices. Besides this fact, it was widely reported that soil loss reduction is very effective immediately after construction. Consequently,early study could result in significant reduction of soil loss and less improvement on crop yield. The impacts of the physical soil and water conservation practices can be classified into short- and long-term effects based on the time needed to become effective against soil erosion (Bosshart, 1997). According to Ayalew (2011) yield was increased by 22 % on some farms and 15 fold on other farms within one year of fanya-juu construction and by >50 % after

3 years with similar farming practices. The work of Ayalew (2011) is in contrast to other studies who reported physical soil and water conservation reduce crop yield during the first years due to disturbance of the top fertile soil and space taken by physical SWC practices (Bedadi, 1993).

Conclusions

Conservation and production impact of physical soil and water conservation are globally a point of discussion. In Ethiopia up to 1980s, reduction of soil loss and runoff was considered as big achievement for experts and government. This created resistance since it did not in line with the objective of subsistence farmers who need production increase in short time. Recently, it was understood SWC practices should also address production objectives. The review showed physical SWC practices well-addressed conservation objectives in reducing run-off, soil erosion and siltation of reservoirs. Despite this, 25% of the reviewed materials showed SWC practices treated area had lower soil fertility than untreated, 12.5% showed no significant change and 62.5% of them showed SWC had positive impact soil fertility either in increasing or maintaining. Reasonably, Physical SWC leads to a reduction in crop yield for the first few years due to the farmland taken by the physical conservation practices and the disturbance of the most fertile topsoil during the construction SWC practices. It can be concluded that the impact of SWC practices over different time periods have not been consistent between crops, plows, socio-economic, soils and climate mainly rainfall. Therefore, researcher should give detail information about the SWC practices under study. For example, climate, slope, erosion level, soil types, age of SWC practices, how they maintained, socioeconomic setting and how farmers manage their field like inputs of chemical fertilizers and land use history. The review discussed in depth why SWC practices have mixed impact on soil fertility and crop yield. In general SWC practices are an action of no option for sustainable development and food security under current land degradation in the form of soil erosion and climate change.

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