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# Effect of Soil and Water Conservation Measures and Challenges for its Adoption: Ethiopia in Focus

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## ABSTRACT

Soil erosion and its consequences is one of the more serious problems in Ethiopia. Various forms of efforts to control the soil erosion through introduced Soil and Water Conservation (SWC) measures have been underway for nearly four decades. Farmer's adoption rates and effects of SWC on soil loss, moisture retention, labour demand and crop yield have been reviewed here. Literature shows that SWC measures have promising effects on reducing soil loss, trapping a significant quantity of sediment at early stages and improving soil moisture. Crop yield improvement was repeatedly reported especially after two to five years of the structure and frequently in low rainfall areas. But an intensive labour requirement and other biophysical and socioeconomic factors discourage farmer's adoption of SWC structures. In the conclusion and recommendations section, major constraints of past approaches and amendment possibilities are discussed.

**Key words:** Crop yield, farmer's adoption, food security, soil erosion, sediment, water retention

## INTRODUCTION

In most developing countries, agriculture remains one of the largest sectors in the economy both in terms of its contributions to the GDP and generating employment (Shiferaw and Holden, 1999). Efficient soil management is a must, not only for agriculture, but also in development as it can have a huge impact on addressing issues of poverty and food security. Therefore it is substantial to exercise environmental rehabilitation, such as reducing soil erosion, for survival and development by implementing appropriate approaches and technology. Soil erosion hampers agricultural productivity by deteriorating soil quality. Even though the effects of soil erosion vary by management and location, soil erosion deteriorates the chemical property of soil by loss of organic matter and loss of minerals containing plant nutrients (Zougmore *et al*., 2009). Soil erosion also exposes subsoil minerals with low fertility or high acidity. Soil erosion causes changes in physical properties of soil such as texture, infiltration rate, bulk density, available water holding capacity, depth of favorable root growth, etc.

Intolerable soil erosion and its impact occurs when the practiced farming system fails to take into account the ease with which soil can be washed away. Due to inappropriate farming systems and less attention given to conservation, soil erosion has been one of the major problems in Africa. In the tropics, there were isolated accounts of erosion from local agricultural staff during the 1930s and 1940s and in 1945 soil conservation became part of the agricultural policy of the colonial period (Young, 1997). Since, decades, attempts have been made to tackle soil erosion problems using different approaches and programmes in many countries for sustainability of agricultural production. Watershed management, particularly Soil and Water Conservation (SWC), supports sustainable livelihoods through reducing environmental degradation and increasing crop production (as it increases infiltration and reduces erosion as well as maintains soil fertility).

For sustainability of livelihood, in some case profitability in any intervention is indispensable. To maintain farm incomes and reduce externalities associated with erosive agricultural techniques, considerable efforts have been directed toward identifying and promoting profitable soil conservation strategies in low-income countries (Shively, 1997). The use of conservation practices in agricultural production is determined by the different income-earning strategies themselves and in combination with some of the biophysical and socio-economic conditions (Jansen *et al.*, 2006). In the livelihood strategies improved production and productivity is the major target. Productivity and conservation objectives are highly complementary, because conservation of soil, water and natural vegetation leads to higher productivity of crops and livestock and thus improvement of livelihoods (Kerr, 2002). According to Kerr (2002), the complementary relationship between productivity and conservation explains the importance and popularity of watershed development among planners, but the relationship with poverty alleviation is ambiguous because net benefits are skewed toward the wealthiest landowners while the poorest people bear many of the costs.

Diminishing productivity due to soil erosion-induced degradation of agricultural land has been of great concern (Amsalu and de Graaff, 2006). Measurements from experimental plots and micro-watersheds in Ethiopia estimated an annual soil loss of about 42 t $ha^{-1}$ from croplands (Bekele and Drake, 2003). Soil erosion and the consequential land degradation, has been recognized to as a serious problem in Ethiopia since 1973-74, subsequent to the devastating famine of the time (Dejene, 2003; Bewket, 2007). In Ethiopia, the traditional stone bunds on agriculture land is commonly practiced since many century in the Tigray highlands and North Shewa. Similar and related activities are practiced in Konso (where landscaping is recognized as a UNSECO heritage site 2011; Fig. 1), Hararghe highlands (Osman and Sauerborn, 2001; Fig. 2) and the Drashe area (Fig. 3) to reduce soil degradation and increase SWC. In limited areas, such as Wondo Genet, farmers build soil bunds for conserving water, especially for growing sugarcane.

In Ethiopia, significant SWC activities were implemented during the 1970 and 1980s by mobilizing farmers through their peasant associations, mainly in food for work programs (Bewket, 2007). This approach was criticized for its top down approach. In many parts of the country, the current government has also been undertaking SWC through integrated and participatory watershed development approaches to improve rural livelihoods with sustainable natural resource management. In the government plan of 2006-2011, Plan for Accelerated and Sustainable Development to End Poverty (PASDEP), one of the goals was to enhance food security through improved natural resources management (MoFED, 2006). The ongoing 30 day national SWC-based watershed management campaign which started in 2010/11 and is expected to continue, also indicates the motive of the government and farmers to conserve soil. This campaign mainly promotes and implements physical SWC measures such as level soil bund, level *fanya juu*, stone bund, etc and undertakes planting billions of seedlings every year at the national level.

This study reviews:

- The role of introduced SWC on reducing soil loss, retaining moisture and improving crop yield
- Adverse effect of introduced SWC measures
- Factors contributing for poor adoption by farmers

Fig. 1: Traditional stone bunds in Konso area

Fig. 2: Stone bunds in Harerghe, Diredawa watershed

Fig. 3: Sorghum stalk traditionally lied in strip to conserve SWC in Derashe area, Southern Ethiopia

## SOIL AND WATER CONSERVATION: PRINCIPLE AND IMPORTANCE

The prevention of accelerated soil erosion (which is the reduction of the rate of soil loss to approximately the rate that would occur under natural conditions) relies on selecting appropriate strategies for soil conservation which in turn requires a thorough understanding of the process of erosion (Morgan, 1995). SWC is important to control the loss of nutrients from agricultural land, to prevent pollution of water bodies, to decrease rates of sedimentation in reservoirs, rivers, canals and ditches and to limit crop damage by wind-blown deposits or burial beneath water. Interest in controlling soil erosion and maintaining soil quality has been stimulated by renewed awareness that soil is vital to both the production of food and fiber and global ecosystem function (Norton *et al*., 1999).

Soil conservation has become an integral part of land use and receives support within a social and economic environment which is conducive to the maintenance and improvement of soil capital (Dudal, 1981). The ultimate aim of soil conservation is to obtain the maximum sustained level of production from a given area of land whilst maintaining soil loss below a threshold level which, theoretically, permits the natural rate of soil formation to keep pace with the rate of soil erosion (Morgan, 1995).

Primary principles of controlling soil erosion by water include reducing raindrop impacts on the soil, reducing runoff volume and velocity and increasing the soils resistance to erosion (Troeh *et al*., 1980). There are two technical means for achieving these principles of soil and water conservation: The barrier approach and the cover approach (Young, 1997). The barrier approach is to check runoff and soil removal by means of contour-aligned barriers. These may be terraces such as soil bunds, *fanya juu*, stone bunds, hillside terraces and grass strips or hedgerows. Barriers either divert runoff into safe channels, such as grassed waterways, or reduce it by promoting infiltration. The barriers are commonly introduced to many new areas of Ethiopia and it has also been practiced traditionally for a considerably long period.

The function of terraces in humid areas are to decrease the length of hillside slopes and thereby reduce erosion and allow for sediment to settle, whereas in drier areas it serve to retain runoff and increase water available for plant growth (Schwab *et al*., 2002). A conservation technique may be regarded as successful if it reduces the rate of soil loss to less than 20 percent of the rate without conservation and to less than 10 t $ha^{-1}$ $year^{-1}$ which is the commonly accepted as a 'tolerable' rate of erosion (Young, 1997).

## ROLE OF SWC IN REDUCING SOIL LOSS AND RETAINING MOISTURE

As discussed in the previous section, the fundamental roles of SWC structures are to significantly reduce soil loss and its consequences. Practically, the loss that can be reduced by the structures is not only soil particles but also essential plant nutrients and applied fertilizers. The SWC measures are identified as the first line of defense that mostly acts as barrier due to the creation of obstacles against surface runoff. The major barriers are a channel/basin and embankment of structures. The reduction of slope length between structures also reduces the volume of runoff and thereby reduces soil loss. Most structures gradually develop to bench and decrease the slope gradient and velocity of runoff. Owing to these characteristics of the structures, Tenge *et al*. (2005) reported that grass strips, bench terraces and *fanya juu* reduced soil loss by 40, 76 and 88%, respectively, compared to the land without those structures. Herweg and Ludi (1999) reported that in the Anjeni area of Ethiopia, graded soil bund reduced soil loss by 40% and whereas graded *fanya juu* reduced soil loss by 50 percent, as compared with untreated plots. Tesfaye (2008)

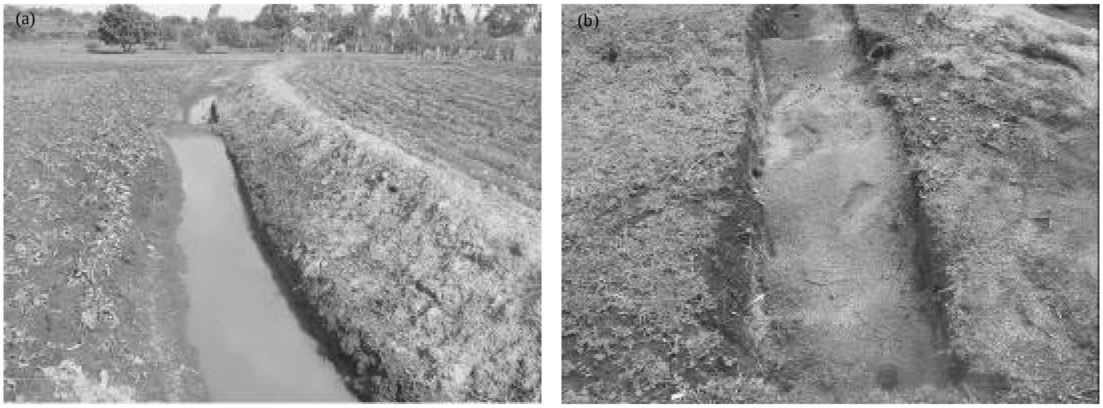


Fig. 4(a-b): Soil bunds in (a) Hadiya and (b) Lake Hawassa watershed shows water and sediment trapping ability

reported that annual soil loss from croplands with level soil bunds reduced by 51% when compared to the control plot. In Debre Mewi, Ethiopia, stone bund and soil bund reduced soil loss by 72.9 and 83.7%, respectively compared to non-treated land (Teshome *et al*., 2013).

In northern Ethiopia, especially in Tigray, stone bund effective in reducing soil loss by 68% particularly at its early age. Its effectiveness decreases as the depression on the upslope side of the bunds accumulates sediment and thus requires frequent maintenance to sustain the effectiveness (Gebrernichael *et al*., 2005). Another study in the Tigray region found stone bunds can trap 64% of the soil moved by water erosion (Vancampenhout *et al*., 2006). Even though soil bunds reduced soil loss by 47% in experimental site established in the central highlands of Ethiopia when compared to the non terraced land, the absolute soil loss from the terraced site was still high (24 t $ha^{-1}$ $year^{-1}$) (Adimassu *et al*., 2012) and required certain improvements/support measures to reduce absolute soil loss to a recommended tolerable range (Young, 1997; Schwab *et al*., 2002). The SWC reduced soil loss by at least 61% in the Tigray region (Girmay *et al*., 2009) and in the Somali region (Welle *et al*., 2006), compared to untreated site. The experiment conducted in Burkina Faso indicated that stone rows and grass strips alleviated soil loss by 84 and 71%, respectively (Zougmore *et al*., 2009).

The channel and embankment of the physical SWC structures impound excess water (Fig. 4) and enhance the possibility of its infiltration which otherwise takes surface runoff. As a result of this role, soil moisture can be improved which is determinant for cropping in medium and low rainfall areas. In Tanzania, the physical SWC measures (bench terrace, *fanya juu* and grass strap) were effective in conserving moisture (26-36%) compared to the land without those structures (Tenge *et al*., 2005). The yield and biomass gradient showing the higher value at the upslope of the stone bund is attributed to, among other things, the moisture-conserving role of those structures (Vancampenhout *et al*., 2006). The second order stochastic dominance analysis in the Hunde-Lafto area, in eastern Ethiopia, implied SWC mitigated the adverse effects of moisture stress in crop production, especially in the case of unfavorable rainfall (Bekele, 2005).

## EFFECT OF SWC ON IMPROVING CROP YIELD

The soil system remains a major determinant of crop yields when compared with plant genetic potential and weather because of the environment it provides for root growth (Olson *et al*., 1999). Thus, increasing and sustaining agricultural production should aim not only at sustaining higher levels of useful biological productivity but also at ensuring that the system is stable enough to maintain soil quality (Dudal, 1981). The key soil characteristics that affect agricultural yield sustainability are nutrient content, water holding capacity, organic matter content, soil reaction, topsoil depth, salinity and soil biomass (Norton *et al.*, 1999). The relationship between soil erosion and soil productivity is complex and involves various factors which often depend on each other (Ludi, 2004). The effect of erosion on soil properties and hence crop productivity varies with location and management (Olson *et al.*, 1999). In general, the loss of organic matter and minerals containing plant nutrients influence crop production (Young, 1989; Lal, 1996; Norton *et al.*, 1999; Olson *et al.*, 1999; Ludi, 2004; Alemayehu *et al.*, 2006). Erosion can also have a direct effect on production through the formation of rills and the subsequent washing out of seeds or through accumulation of eroded materials on germinated crops (Ludi, 2004). However, total soil loss is the single most important factor in explaining productivity changes (Ellis-Jones and Tengberg, 2000). The total soil loss can be reduced (as discussed in the previous section) by physical SWC measures, among others.

Productivity and SWC objectives are highly complementary because conservation of soil, water and natural vegetation leads to higher productivity of crops and livestock and thus the improvement of livelihoods (Kerr, 2002). Ellis-Jones and Tengberg (2000) assumed that without any SWC, crop yields will decline approximately by 1.5% year$^{-1}$, being equivalent to a 30% decline over 20 years. The SWC structures not only act as a partial barrier to water-induced erosion but also form a total barrier to tillage erosion (Gebrernichael *et al.*, 2005).

The physical SWC measures are considered as investment for which significant benefits are expected later and for years to come. However, practical models and empirical equations are less available to estimate effects of SWC structures, as they touch many parameters and create complex interactions. In addition, the off-site role is less feasible to estimate and commonly ignored even in existing estimations and computations.

The short-term effects of bunds or terraces are the reduction of slope length and the creation of small retention basins for runoff and sediment and to reduce the quantity and eroding capacity of the overland flow (Nyssen *et al.*, 2007). The medium and long-term effects of bunds include the reduction in slope angle by forming bench terraces (Alemayehu *et al.*, 2006). In the long term, slow-forming terraces induced by bunds are often associated with a high spatial variability in soil fertility and crop response which is due to water and tillage erosion in between structures (Nyssen *et al.*, 2007).

Ludi (2004) calculated soil loss depth in land with conservation structures and in non-terraced fields in experimental sites in Maybar andit Tid and Anjeni, Ethiopia. The results showed that soil loss from non-terraced cropland was higher. Other comparisons made between local cultivation and SWC structures at experimental sites in Ethiopia showed that soil loss is reduced significantly for the majority of SWC treatments, such as level bunds, but production rarely increased as a result of SWC in three to five years of age (Herweg and Ludi, 1999). The study by Bekele (2005) in the Hunde-Lafto area in eastern Ethiopia showed that SWC resulted in higher yields in unfavorable rainfall conditions.

In semi-arid Burkina Faso, combining compost and stone rows/grass strips induced a 79% reduction in soil loss compared to the control (Zougmore *et al.*, 2009) and increased sorghum biomass production (Zougmore *et al.*, 2004). Stone bunds can reduce soil loss by 68 percent (Gebrernichael *et al.*, 2005). Plots with stone bunds are more productive than those without such technologies in semi-arid areas but not in higher rainfall areas; apparently this is because the moisture conserving benefits of this technology are more beneficial in drier areas (Menale *et al.*, 2007). Schwab *et al.* (2002) reported that in drier areas terraces serve to retain runoff and increase the amount of water available for crop production or for recharging shallow aquifers.

Grass strips, bench terraces and *fanya juu* have increased maize yields by 29.6, 101.6 and 50.4% and bean yields by 33.3, 40 and 86.7%, respectively when compared to land without those structures (Tenge *et al.*, 2005). The effect of SWC structures is observed after some years of the structure being built. In three year old structures, Teshome *et al.* (2013) observed 10 and 15% yield increments in Debre Mewi and Anjeni (Ethiopia) watersheds, respectively, when compared to the yield before constructing those structures (*fanya juu*, soil bund). In this study, yield declined in the first and second years. In line with this, Wolka *et al.* (2013) reported that 79.3% of the interviewed farmers perceived the increment of yield after 2 years of SWC structures (the soil bund and stone bund) were put in place. Herweg and Ludi (1999) indicated a 4-50% decline in yield during the first 3-5 after the construction of SWC measures due to water logging problems; this was followed by subsequent yield increases ranging from 4-15%.

Nyssen *et al.* (2007) found that after a few years of its construction, stone bunds increased cereal and teff yields by 8 and 11%, respectively, even by considering the area lost due to the conservation structures. Indigenous stone bunds (*Kab*) have increased sorghum yields by 56-75% compared to other non-terraced land in north Shewa, Ethiopia (Alemayehu *et al.*, 2006). Kato *et al.* (2011) indicated that stone bunds, soil bunds and grass strips have a robust and positive output on crops in the low rainfall areas of the Blue Nile basin in Ethiopia and high risk reducing effects in high rainfall areas. This study indicated that grass strips have the highest production elasticity among SWC technologies in this low rainfall area. In these areas soil bunds have risk reducing effects. The stone bunds aged 3-21 years increased crop yield by 0.58-0.65 t $ha^{-1}$ in Tigray, Ethiopia (Nyssen *et al.*, 2007).

Stone bunds (Fig. 5) contribute to agricultural productivity due to its moisture conserving role. Results of the analyses based on multiple plot observations per household showed agricultural plots with stone bunds are more productive than those without it in dry areas but not in the high rainfall areas of northern Ethiopia (Kassie *et al.*, 2008). Vancampenhout *et al.* (2006) computed the yield change on land with stone bunds and estimated a 7% increment compared to non-terraced land. The first order stochastic dominance analysis in eastern Ethiopia suggests SWC results in higher yields and net return for farming households (Bekele, 2005). In the central Kenyan highlands 82% of farmers perceived that SWC structures increased crop yields (Okoba and de Graaff, 2005).

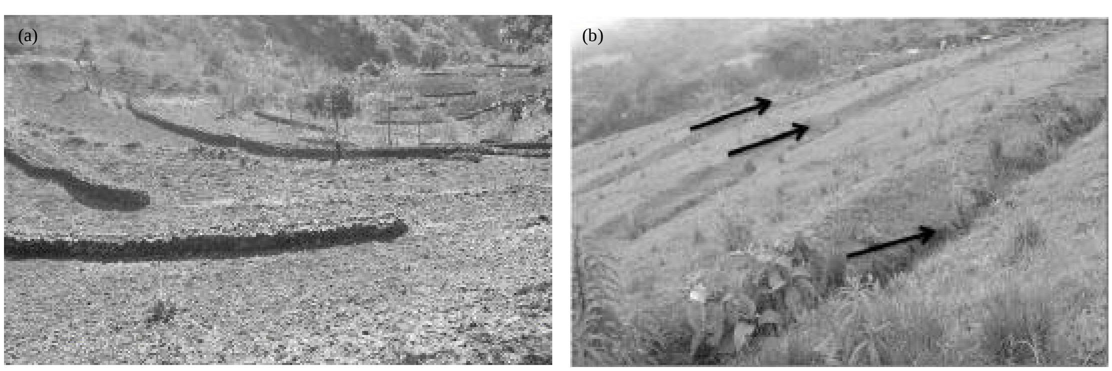


Fig. 5(a-b): Typical (a) Stone and (b) Stabilized soil bunds at Dawro

Soil bund effects on rice production were studied in Southeastern Tanzania and yield comparison showed that, generally, soil bunds can appreciably increase the production of rain-fed lowland rice (Raes *et al*., 2007). In the central highlands of Ethiopia, the soil bund reduced the yield of barley by 7% when the space occupied by the structures are taken into account and otherwise increased yield by 1.7% (Adimassu *et al*., 2012).

## PROBLEMS OF SWC STRUCTURES

**Decrease in total cultivable area:** Owing to the requirement of the design, physical SWC measures demand cut and fill and/or the mounding of stone and soil in graded or level alignments. Therefore, the channel and embankment have different landforms than the area between inter-structures. Spacing of the structures depends mainly on the slope of the land. In some cases, these structures lead to modification sof land use and management, example species that can be grown to strengthen embankment need to be introduced and managed. Means of inter-structure area cultivation may change.

In the developing world, where the growth of population directly depending on cultivable land is higher, the total decrease of cropping land as a result of SWC structures become challenge. Reports indicate that, depending on slope and structure type, significantly high proportions of cultivable land are occupied by structures. Depending on slope (for a slope category from 5 to greater than 55%) and soil stability, grass strips, bench terraces and *fanya juu* occupy 1-15, 5-42 and 8-40% of cultivable land areas, respectively (Tenge *et al*., 2005). In Ethiopia, it was recommended that *fanya juu* occupies 2-15% of the land area for a slope of 3-15%, stone bunds occupy 5-25% for a slope of 5-50% and soil bunds occupy 2-20% for a slope of 3-30% (Teshome *et al*., 2013). Vancampenhout *et al*. (2006) estimated that stone bunds occupy about 8% of the farmland in northern Ethiopia. In experimental plots established in the central highlands of Ethiopia, soil bunds occupy 8.6 percent of cultivable land (Adimassu *et al*., 2012).

**Labour requirement:** The technological options are less available in developing countries to relieve humans. As result farm execution of most farm related activities require human labour, among other. The construction and maintenance of physical SWC structures require intensive human labour for which machinery has not been developed or introduced in most developing countries. The labour demand appears much more than the requirement for most ordinary farming businesses. Even though the durability of structures mainly depends on slope, rainfall intensity, soil stability and land use as well as management at the upper watershed and in inter-structure, it, in general, requires frequent maintenance such as de-silting, repairing broken parts, etc. In the current Ethiopian strategy, there is a moral and policy obligation to send children to school which is comparatively less strict in the near past and more labourers engage in farming activities in rural areas. For households, thus, labour may remain a challenge for the undertaking human labour based SWC activities.

Construction of soil bunds requires 75 and 150 persons per day (PD) $ha^{-1}$ in Debre Mewi and Anjeni watersheds, respectively. In those watersheds, stone bunds requires 125 PD $ha^{-1}$ and in the Anjeni watershed *fanya juu* demands 150 PD $ha^{-1}$ (Teshome *et al*., 2013). Depending on slope and soil stability, grass strips, bench terraces and *fanya juu* require 7-388, 66-592 and 43-388 labour $day^{-1}$, respectibely, to cover a one hectare land area (Tenge *et al*., 2005). A guideline by the Ethiopian ministry of Agriculture estimates 150-250 PD for the construction of one kilometer of commonly practiced SWC structures, such as soil bunds, *fanya juu*, stone bunds, etc. (Lakew *et al*., 2005).

**Farmers' adoption of SWC:** In Ethiopia, the problem of intolerable soil erosion and its adverse effects has been repeatedly reported for many watersheds. The traditional physical SWC measures, such as stone terraces, have been practiced in a few areas for several hundred years (e.g., Konso area (Tadesse, 2010), for which awareness and experience have been confined in that particular area. The structures having certain technical designs and specifications have been introduced to many new areas, assuming that land users can adopt it sooner or later. Since, the 1970s, pilot projects, campaign work, food for work programs (grain and edible oil support), etc. were initiated and are ongoing by both government and non-governmental organizations.

However, not with standing promising outcomes in insignificantly small projects/areas, such as in a few watersheds of Tigray and Kambata Tambaro, the SWC efforts have apparently had little success despite four decades of numerous attempts. Soil erosion and land degradation appear to be serious problems for which previously exerted efforts brought insignificant change. Studies indicate that even though farmers are aware of the problem, their own initiative and investment to control soil erosion is minimal, even in conditions where serious erosion is recognized (Shiferaw and Holden, 1999; Moges and Holden, 2007).

Furthermore, maintaining and adopting the introduced technology has been challenging. Site-specificity of socio-economic and biophysical factors are considered problems. The actual and long term financial profitability to farm households critically influences the process of accepting and replicating such structures (De Graaff *et al.*, 2008). Poverty and a long time span to get return from soil conservation activities reduced adoption of SWC technologies in East Shewa (Ethiopia) (Shiferaw and Holden, 1999). For the Dedo area (Ethiopia), Anley *et al.* (2006) reported that age and distance to plot from home has a negative influence, but formal education, frequency of extension agent visit and area of cultivated land has a positive influence on soil bunds, cut-off drains and *fanya juu*.

In the northwestern Ethiopian highlands, labour shortage, problems with fitness of the SWC technologies to the requirements of farmers and land tenure insecurity discouraged farmers from adopting SWC measures such as soil and stone bunds, *fanya juu*, etc. (Bewket, 2007). In northern Ethiopia, long-term investments on stone bunds were influenced by farmer's capacities to invest and land tenure security, but investment on soil bunds were influenced by labour and foregone land productivity (Gebremedhin and Swinton, 2003). Positively influencing factors of adoption in the eastern highlands of Ethiopia include plot area, access to information, support programmes for initial investment and slope, whereas family sizes (decreasing land/man ratio) negatively influence adoption (Bekele and Drake, 2003). In the Baressa watershed, age, perception of profitability, farm size and steep slopes positively influenced adoption and livestock number and high fertility negatively influenced adoption (Amsalu and de Graaff, 2006).

In Burkina Faso, among the analyzed parameters, education, perception, farmer association membership and area of land cultivated had a positive role for the adoption of SWC (stone strips or zai) (Sidibe, 2005). In the west Usambara highlands of Tanzania, farmers responded that involvement in off-farm activities, insecure land tenure, location of fields and a lack of short-term benefits negatively influenced adoption of SWC measures (i.e., vegetative strips, bench terraces, *fanya juu*, etc.), whereas memberships in farmer groups, level of education and contacts with extension agents positively influenced the adoption of those measures (Tenge *et al.*, 2004). In general, head of household age, slope, farm size, attitudes towards conservation and participation in the programme influenced adoption, whereas profitability and labour requirements influenced continued use in some developing countries such as Ethiopia, Tanzania and Mali (De Graaff *et al.*, 2008). In the north Pare and West Usambara of Tanzania, participation in SWC programmes, ranking of soil erosion as a priority in agriculture production, participation in labour-sharing groups, having an off-farm income, farm size and knowledge of soil erosion positively influenced adoption of SWC (Mbaga-Semgalawe and Folmer, 2000). Farmers in the central Kenyan highlands perceived that a shortage of labour, capital, farm tools relevant to the work and knowledge on the construction of SWC technologies influenced their adoption rate (Okoba and de Graaff, 2005). In Kenya, social components such as associations or group memberships in voluntary associations, trust and community positively influenced adoption of SWC (Nyangena, 2008).

## CURRENT IMPLEMENTATION STRATEGY AND APPROACH

Soil erosion and land degradation remain a serious challenge for food security efforts and other development endeavors such as the siltation of dams. As discussed earlier, the projects and programmes implemented for more than three decades were poorly repaired and adopted by farmers. Few exemplary achievements of SWC based watershed management have attracted the government. With the intention of replicating these achievements a roughly thirty-day public campaign to undertake SWC based rural watershed management has been considered as a strategy and was launched early 2011. The activity has been well publicized and politicized in some regions (Tigray, Amhara, Oromia and Southern Nations, Nationalities and Peoples Regional State) of Ethiopia. Different groups of the society (i.e., teenager school boys and girls Fig. 6, adults, women,

Fig. 6: Teenagers in public campaign for soil bund construction at Dawro, Omo basin

men etc) participated in this activity. It has been undertaken during the dry season when the farmers were comparatively less busy with their cropping activities. The selected season is a favorable period for protecting the soil from rainfall which is expected after the dry season and has more eroding possibilities as the land is bare.

The government and experts might have accumulated sufficient technical and theoretical lessons and experiences. However, it appeared that building the structures with any approach is not the challenge, but shifting farmers' minds or convincing them to replicate and adopt the technology are still much further behind than they should be. In many watersheds, reports and field observations confirm that structures are rarely maintained when damaged or broken by livestock, floods, etc. The campaign work annually focuses on building new structures but not auditing or monitoring the previous labour and time investments of similar activities.

## CONCLUSION

Not withstanding exemplary traditional efforts in small localities in Ethiopia, annual crop and animal husbandry are generally exploitative. Removal of forests and woodlands from fragile landscapes, cultivation of steep and marginal lands and over grazing and trampling are major problems. The land users give limited attention leading to interventions of the situation even in areas where serious degradation takes place. The issue of land degradation and its effect on food security coupled with periodic drought has attracted the attention of governments for more than the past four decades.

Since, the 1970s, significant efforts were made to introduce improved SWC measures to areas prone to such problem, especially in northern Ethiopia. In addition to the government efforts, many international and local NGOs have been involved in problematic areas. However, strong attention was paid to building the structures partially sticking to recommended design and specification. But little attention was given to create reliable awareness on land users. As a result, the structures built by either a public campaign or any form of temporal incentive existed in place for a short period. Some were demolished hoping to reconstruct it and raise incentive for another round; others link the intervention with land tenure insecurity (assuming the government may take their land). By nature, the structures require frequent maintenance due to their sediment trapping characteristics, vulnerability to livestock damage, intensive rainfall, etc. The subsequent management and modality for maintenance is not clearly planned and agreed upon in such a way that it can enforce anyone to act.

Along with those problems, the technical bias was looks leaned toward physical SWC. In principle and practice, the biological measures are the cheapest, most easily adoptable and effective measures, but little attention was given. In cultivable land, the compatibility of species with intended annual crops to be grown in inter-structure, poor survival of some species is an issue as the land is subjected for open grazing during off-seasons, lack of seed or seedling supply, lack of clear research outcomes to select species, etc may contribute to challenges on scaling up biological measures on such land use.

The reviewed literature indicated that the physical SWC structures reduced soil loss significantly compared to non-terraced areas and improved soil moisture retention which is a limiting factor for crop production in dry and semi dry areas. Increased crop yield has been reported for many areas as a result of structures, especially in moisture deficit areas. Even though those quantified effects and the role of SWC on runoff and flood regulation/control have been recognized, adoption of the structures is still low.

Despite farmer's awareness on soil erosion problems and government/NGO efforts, etc, farmers' adoption of the structures remains below expectation. Reasons are site-specific and the commonly cited factors that positively influence the adoption processes include: Formal education, frequency of extension agent visit, area of cultivated land, access to information, slope of the land, perception of profitability, trust, ranking of soil erosion as a priority in agriculture production and membership in a farmer association. Some socio-economic and biophysical components such as distance of plot from home, family size, livestock number, high fertility, insecure land tenure, shortage of labour and capital, problem of fitness of the SWC technologies, foregone land productivity and lack of short-term benefits are listed as negatively influencing factors of the adoption. Regarding the age and off-farm income, varying influences were observed in different areas.

The current SWC based watershed management activities which are carried out by various approaches/organizations, including massive public campaign, NGOs, safety nets, etc., should intensively work on awareness of the land users so that rate of adoption can be improved. Technical support and monitoring should be strengthened to select the appropriate structures, design and specification. Wherever, possible, biological measures such as exclosures, tree and shrub planting and management, agroforestry, strengthening the structures with grass or shrub, etc., should be given priority due to their multiple and sustaining roles. Many cases studies indicated that biological measures and soil fertility management could improve effectiveness of the structure and soil fertility (Zougmore *et al.*, 2002; Adimassu *et al.*, 2012). The technical approach should also give due attention for livestock management which significantly creates conditions for soil erosion and damage of the built structures.

The promising pilot achievements indicated the importance of these activities. But challenges are observed for the adoption of the structures. Therefore, strong biophysical and socio-economic research is important to improving the effectiveness and adoption of those structures for Ethiopian conditions.

Furthermore, since preventing soil erosion is safer and cheaper than controlling it, land use plans and policies should be practiced primarily for careful management and utilization of fragile and marginal areas. The policy and regulation aspect should also include transparent and enforcing commitments for maintaining/repairing the structures after they have been built by various approaches. The current motive and mobilization for SWC based participatory watershed management should be sustained and the strategy should be strengthened by national policies. For better effects, intervention should always follow watershed logic, commencing from uphill and progressing down toward the watershed outlet, but they should not be implemented in fragmented distributions.

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