Effect of Soil and Water Conservation Measures on Land Degradation Under Climate Change Scenario in Ethiopia: A Review of Work

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Abstract: Land degradation and its consequences is one of the more serious and complex problems in the developing country particularly in Ethiopia. Land degradation results primarily from incorrect land use and bad land management practices. Review of the study indicated that Causes for land degradation were: human population growth, poor soil management, deforestation, insecurity in land tenure, variation of climatic conditions, and intrinsic characteristics of fragile soils in diverse agro-ecological zones. Various forms of efforts to control the land degradation through introduced Soil and Water Conservation measures have been undertaken for several years. Farmer’s adoption rates and effects of SWC on soil loss, moisture retention, and crop yield and climate change have been reviewed. Literature shows that SWC measures have promising effects on reducing soil loss and runoff, trapping a significant quantity of sediment at early stages, mitigate climate change, improving soil moisture and increases soil fertility. Crop yield improvement was repeatedly reported especially after two to five years of the structure and frequently in low rainfall and drier areas. Due to conservation effects carbon sequestration have been commenced as an effective tool for adaptation and mitigating climate change or extreme weather events in the country. This paper suggests, based on a review of the literature, that Management decisions regarding conservation practices, such as mulching, con-servation agriculture, and returning crop residue to the field to increase nutrient cycling, can contribute to carbon sequestration and help us mitigate and adapt to climate change But an intensive labour requirement and other biophysical and socioeconomic factors discourage farmer’s adoption of soil and water conservation structures. Our review suggests that without management decisions that increase soil and water conservation, food security for the world’s growing population will be harder to achieve.

Keywords: SWC, Land Degradation, Adaptation, Climate, Mitigation, Ethiopia.
1. INTRODUCTION

Soil degradation is a global threat (Cerdà et al., 2010; Mighall et al., 2012; de Souza Braz et al., 2013; Wang et al., 2013). It has been affecting about two billion hectares of land (Oldeman et al., 1991). While no region is immune, developing countries are more severely affected by soil degradation than developed countries. Ethiopia, one of the developing countries in eastern Africa, is highly threatened by soil degradation problems (Hurni et al., 2007). Soil degradation is a serious problem in Ethiopia, particularly in the highlands, where population density is high and the bulk of crop production occurs (Haile & Fetene, 2012; Karltun et al., 2013; Belay et al., 2014). The Ethiopian highlands Soil erosion is a severe problem in sloping areas, especially in the northern and central highlands where vegetation cover is very low and soils are already very shallow (Jabbar et al., 2000).

The pressure from human and livestock populations, coupled with biophysical, social, economic, and political factors, has caused severe degradation of resources and climate changes (Sonneveld, 2002; Girmay et al., 2008). Depletion of soil organic matter (SOM) and nutrients, salinization, and soil erosion by water were the most critical forms of soil degradation (Bewket, 2003; Girmay et al., 2008) and are exacerbated by deforestation. Soil erosion varies with soil types (erodibility) and erosive factors like slope of the land (length and steepness), rainfall characteristics (volume, intensity and duration), soil cover and land management (Prasannakumar et al., 2012).

Soil erosion by water is by far the most prominent process of soil degradation in the highlands (Haile & Fetene, 2012; Haregeweyn et al., 2013). It causes an annual loss of 30,000 ha (0.03%) of land area (EC-FAO, 1998; National Review Report, 2002) and 1.5Mg billions of soil and severely damages over two million hectares (Hurni, 1993). Soil erosion is severing in the weyna-dega and dega (cool) zones, which mainly have rugged topography and cover over 60% of the area (WDNRMD, 2013).

Over the past three decades, per capita food production in Ethiopia has declined from about 280 to 160 kg y⁻¹ (Awulachew, 2010). As (Mitiku et al., 2006) reported that crop yield is declining by 1–3% y⁻¹, but the population is growing at a rate of 3% y⁻¹, leading to a serious food–population imbalance. Ethiopia has often faced food deficit in the past (Bewket, 2003) and may also face even more severe shortages in the future. Soil degradation also increases vulnerability of people to the adverse effects of climate variability and change, by reducing SOC concentration and water holding capacity, which in turn reduces agricultural productivity and local resource assets (TerrAfrica, 2009).

Sustainable soil management technologies can enhance the SOC stock, reduce soil degradation, increase crop productivity and decrease soil’s vulnerability to climate change. In addition, judicious soil management can increase people’s capacity to adapt and mitigate climate change through carbon (C) sequestration and greenhouse gas (GHG) emissions reduction (Vagen et al., 2005; TerrAfrica, 2009). Soil C sequestration can improve soil quality, restore degraded ecosystems, and increase agronomic/biomass productivity. Thus, C sequestration is often termed as a win–win or no-regrets strategy (Lal et al., 2003; Girmay et al., 2008).

The decline in agricultural productivity and poor quality of natural resources signify the necessity of initiatives that integrate resource conservation and development measures in Ethiopia. Therefore, the government of Ethiopia, supported by donors and non-governmental organizations, adopted measures to rehabilitate degraded soils and minimize risks of new/additional degradation (Bewket, 2003; Yitbarek et al., 2010). Also (Girmay et al., 2008 and Kato et al., 2009) reported that significant contribution of SWC technologies on reducing production risks in Ethiopia and opined that these measures may be considered as a “climate-proofing strategy.” Contrarily, (Kassie et al., 2008) argued that physical-based SWC measures did not have a positive impact but reduced yield in the high-rainfall areas of the Ethiopian highlands compared with non-conserved plots. Thus, implemented SWC programs had mixed outcomes, because of poor implementation of good technologies (Merrey & Gebreselassie, 2011). Therefore this work is aimed to review several findings or reports regarding to the impact of SWC measures on land degradation and its implications to climate change adaptation and mitigation in Ethiopia and to share a compiled information for beneficiaries.
This paper reviews on:
a. the causes and consequences of land degradation and climate changes in Ethiopia,
b. the adoptability and challenges of soil and water conservation measures, and
c. effects of conservation practices on land degradation and climate change mitigation.

2. LITERATURE REVIEW

2.1. Soil Erosion and Land Degradation in Ethiopia

Land degradation results primarily from incorrect land use and bad land management (Blum et al., 1998; Mazengia, 2010). Similarly, most studies in Ethiopia have also strengthened this thought. In Ethiopia an estimate 17% of the potential annual agricultural GDP of the country is lost because of physical and biological soil degradation (Tilahun et al., 2007). Causes for land degradation are: human population growth, poor soil management, deforestation, insecurity in land tenure, variation of climatic conditions, and intrinsic characteristics of fragile soils in diverse agro-ecological zones (Bationo et al., 2006). Also (Badege, 2009) pointed out that soil degradation in Ethiopia can be seen as a direct result of past agricultural practices in the highlands. The dissected terrain, the extensive areas with slopes above 16%, and the high intensity of rainfall lead to accelerated soil erosion once deforestation occurs.

The causes and effects of land degradation are complex, and have intermingled environmental impacts. Deterioration of crop production particularly in the highlands is cited as a major and prime impact of the land degradation, where soil and soil nutrient loss due to erosion is a leading cause (Badege, 2001; Nyssen et al., 2009). Although the country has huge hydropower and irrigation potential, environmental degradation, particularly erosion and vegetation clearance in the highlands, is threatening this potential (Tadesse, 2001; Awulachew et al., 2007).

Soil erosion varies with soil types (erodibility) and erosive factors like slope of the land (length and steepness), rainfall characteristics (volume, intensity and duration), soil cover and land management (Prasannakumar et al. 2012). Among the soil types, Luvisols and Nitosols were found to be most vulnerable to water erosion, while Vertisols and Phaeozems were less vulnerable (Herweg and Ludi 1999). Due to erosion, farmlands in many parts of the highlands have shallow soil depths and poor fertility (Ciampalini et al. 2008).

Degradation has also been influencing flora and fauna diversity and negatively impacted the microclimate (Asefa et al., 2003; Tilahun, 2006). Decline of the forest cover also contributed to this problem (Tadesse, 2001). In recent times, frequent droughts, early end and late onset of the main rainy (Kiremt) season and failure of the smaller rainy (Belg) season are linked with climate change and land degradation, which could develop into desertification (Tilahun, 2006).

2.1.1. Impacts of Land Degradation in Ethiopia

Degradation on the earth surface is one of the most sever global problem of our times, which affect 33% of the land surface; with consequences for more than 2.5 billion people. About 40% of the world’s agricultural land is seriously degraded, were 80% of this degradation is caused by soil erosion. This worldwide depletion of land resource continues to be serious hazard particularly, in the main pillar of their economy. Land degradation in Ethiopia account for 8% of the global total (Mazengia, 2010), the north shewa and its districts are among the most strongly affected by soil erosion induced degradation and drought in the northern highland (Dejene, 1990; Mazengia, 2010).

According to study conducted by FAO in 38 sub-Saharan Africa (SSA) countries, including Ethiopia showed that Ethiopia is one of the countries with the highest rates of nutrient depletion. In line to this (Hurni, 1993) also reported as much as 300 ton ha⁻¹ annual soil loss from croplands with average rates of 42 ton ha⁻¹. Similarly, (Herweg and Ludi, 1999) estimated a higher than 110 ton ha⁻¹ annual soil loss from farmlands without terraces. The aggregated national scale nutrient loss was 41 kg ha⁻¹yr⁻¹ for N, 6 kg ha⁻¹yr⁻¹ for P and 26 kg ha⁻¹yr⁻¹ for K (Stoorvogel and Smaling, 1990). Ethiopian highland reclamation study (EHRS) estimated 1.9 billion tons annual topsoil loss from the highlands due to water erosion, which is equivalent to 8 mm soil depth or 130 t ha⁻¹ annual losses. This adverse effect was more sever in the
highland area where 85% of the human and 77% of livestock population are living and agricultural is intensive (Mazengia, 2010).

As estimates from national level studies indicates more than 2 million hectares of Ethiopia’s highlands have been degraded beyond rehabilitation and additional 14 million hectares severely degraded, which is reflected in cereal yield reduction averaging less than 1.2 tons per hectares in most of the highlands (UEMA, 2013). This has significantly contributed to the hunger faced by some five to seven million people in the country, there by requiring external assistance every year for their survival and more than 45% of the total population to toil below the absolute poverty line (Gete et al., 2006).

2.1.2. Land Use/ Land Cover Change and Its Implications on Land Degradation

Land use and land cover are interrelated but not synonyms (Jansen and Gregorio, 2003). Land use is defined as human modification of a natural environment or wilderness into a new environment such as agricultural fields, pasture and settlement, while land cover is the physical cover of the earth surface that can be grass, water, forest, bare ground, crop field and others (FAO, 2000). LULC change occurs due to human and natural drivers. Human-induced changes are associated with socio-economic activities such as agriculture, mining, forestry, forest extraction, wars, settlement and policies. The natural drivers include weather and climatic fluctuations, ecosystem and geological dynamics, and others (Riebsame et al., 1994). However, there have been rapid dynamics in the past century (FAO, 2000). For example, the Global Forest Resource Assessment (FRA, 2005) reported 13 million ha annual forest land conversion to agricultural land at a global scale, while reforestation has been taking place at a very slow rate as compared to the net deforestation, especially in Africa (Jansen and Gregorio, 2003).

The major LULC changes in Ethiopia occurred in densely populated areas, mainly in the highlands (Amsalu et al., 2007; Assen and Nigussie, 2009). The changes were mainly conversion of forest and grasslands into cultivation and grazing. With the increasing population, large forest areas were destroyed and converted into agriculture in response to the ever increasing demand for food, grazing land and wood (Feoli et al., 2002; Assen and Nigussie, 2009). Limited technology and livelihood options have aggravated the competition between different uses, and government policy and tenure have also played a considerable role (Tefera et al., 2002; Assen and Nigussie, 2009). For example, during the emperor period, farmers used traditional shifting cultivation known as Mofer-zent Ersha, where farmers clear forest to get new fertile farmlands (Amsalu et al., 2007; Mekonnen and Bluffstone, 2008). These deforestation have been resulted with today land degradation, climate changes and food insecurity in the country.

2.1.3. Climate Changes in Ethiopia

Climate change is predicted to have major adverse consequences for the world’s ecosystems and societies. Although a global phenomenon, the severity of the adverse effects of climate change will differ significantly across regions, countries and socioeconomic groups. Poor countries will suffer more, with the poorest in the poor countries likely to suffer most. Africa is highly vulnerable to the potential impacts of climate change and Ethiopia is often cited as one of the most vulnerable and with the least capacity to respond and adapt (Thornton et al., 2006).

Ethiopia already suffers from historical climate variability and extreme climatic events (Mesfin, 1984; Pankhurst, 1985; McCann, 1987; IIRR, 2007). In particular, frequent droughts coupled with environmental degradation and decline in food production are common and still remain major challenges to Ethiopia (NMA 2006, 2007; Senbeta et al., 2002; Senbeta, 2006). Droughts and floods are common phenomena in Ethiopia, occurring every 3 to 5 years (World Bank, 2006). The country has experienced many major national droughts since the along with dozens of local droughts (World Bank, 2009). In particular, there is increased incidence of meteorological drought episodes, famines and climate-sensitive human and crop diseases in the northern highland and southern lowland regions of Ethiopia (World Bank, 2009; Aklilu and Alebachew, 2009; Oxfam International, 2010; UN-ISDR, 2010).
2.1.3.1. Adverse effects of climate change on temperature and rainfall in Ethiopia

In many areas of Ethiopia, the frequency of droughts and floods has increased over the years, resulting in loss of lives and livelihoods National Meteorological Agency (NMA, 2007; Oxfam International, 2010). Agricultural production in Ethiopia is dominated by small-scale subsistence farmers, and is mainly rain-fed, thus highly exposed to climate variability and extremes. According to the (World Bank, 2006), current rainfall variability already costs the Ethiopian economy 38% of its growth potential.

Analysis of historical climate data show an increase in mean annual temperature by 1.3°C between 1960 and 2006, translating into an average rate of 0.28°C per decade. The annual minimum temperature increased by about 0.37°C every decade between 1951 and 2006 (McSweeney et al., 2008). In contrast, precipitation remained fairly stable when averaged over the country (Schneider et al., 2008). Similarly, no statistically significant trend in mean annual rainfall was observed in any season from 1960-2006 (NMA, 2006; McSweeney et al., 2008). However, the spatial and temporal variability of precipitation is high, thus large-scale trends do not necessarily reflect local conditions.

Projecting into the future, most global climate models indicate some increase in rainfall in both dry and wet seasons in Ethiopia (NMA, 2006). With regard to temperature, IPCC’s mid-range emission scenario results show that compared to the 1961-1990 average mean annual temperature across Ethiopia will increase by between 0.9 and 1.1°C by the year 2030, and from 1.7 to 2.1°C by the year 2050. The temperature across the country could rise by between 0.5 and 3.6°C by 2080 (NMA, 2006). The increasing temperature combined with rainfall variability will have serious consequences on ecosystems, economic sectors and communities of Ethiopia.

Ethiopia’s NMA identifies drought and flood as the major hazards in the future as well, with potential negative impacts on agriculture and food security (FDRE, 2011). A study based on the Ricardian method predicts that a unit increase in temperature could result in reduction of the net revenue per hectare by US$177.62 in summer and US$464.71 in winter seasons (Deressa, 2007). Understanding the nature of climate change impacts, key vulnerabilities and indigenous adaptive responses at local levels, and the national institutional responses are important for developing appropriate adaptation strategies at community and farm levels.

2.1.3.2. Adverse effects of climate change on water in Ethiopia

In degraded watersheds, opportunities for water harvesting and management are few and of limited use; access roads are continuously damaged by runoff and erosion, access to clean water for domestic use is very difficult and incidence of water-borne diseases is very high. Unstable watersheds induce unstable production systems and inefficiency of input utilization, as erosion and inefficient use of rainwater also undermine efforts to enhance productivity (FAO, 2014).

Climate change affects directly or indirectly all the elements of the water cycle. An increase in temperature results in an increase in evaporation and evapotranspiration. While there are large uncertainties on the impact of climate change on precipitation, models converge in predicting more variability in rainfall patterns, with increased occurrence of extreme events like intense precipitation or longer periods of dry weather (FAO, 2011). These two factors contribute to disruption of the water cycle which affects the soil water holding capacity, leading to longer periods of water deficit and more frequent flood. Such changes will affect rainfed farming, and through increased variations in river runoff and groundwater recharge will also affect irrigated agriculture, as well as livestock feeding and watering. Because of this, the design of climate-proof farming practices needs to be viewed through a water lens (FAO, 2013). They are therefore the best entry point for designing climate adaptation programs.

2.1.3.3. Impact of climate change on soil fertility and soil degradation processes

Climate change may have stronger or weaker, permanent or periodical, favorable or unfavorable, harmful (sometimes catastrophic), primary (direct) or secondary (indirect) impact on soil processes. Among these processes soil moisture regime plays a distinguished role. It determines the water supply of...

As it has been indicated by the findings of (Várallyay G., 2011) primary and secondary impacts of climatic change on various soil degradation processes: Soil erosion; there are no linear relationships between mean annual precipitation, surface runoff and the rate of erosion. The rate, type and extension of soil erosion depends on the combined influences of climate (primarily the quantity and intensity of rainfall), relief, vegetation (type, continuity, density), and soil erodability characteristics. Acidification; Decreasing precipitation may reduce downward filtration and leaching. Climate determines the dominant vegetation types, their productivity, the decomposition rate of their litter deposits, and influences soil reaction.

On the other hand consequence of the expected global ‘warming’ is the rise of ecstatic sea level: increase of inundated territories (especially in the densely populated delta regions and river valleys), and the areas under the influence of sea water intrusion.

2.2. Adoption and Failure of Soil Conservation Measures in Ethiopia

In response, government and development agencies have invested substantial resource in promoting soil-water conservation practices as part of efforts to improve environmental conditions and ensure sustainable and increased agricultural production. Despite the increasing efforts made and the growing policy interest, adoption of those technologies by smallholder farmers outside of intensively supported project location has generally been. Regardless of all those, effort the natural resource base is deteriorating from time to time and becomes major cause for food insecurity and vulnerability (Berhanu et al., 2009).

Soil and water conservation technology is one which is implemented since the mid1970s in Ethiopia (Alemu, 1999). Since then, huge areas have been covered with terraces, and millions of trees have been planted (Yeraswork, 2000). Typical SWC technologies used in Ethiopia include soil bunds, stone bunds, grass strips, waterways, trees planted at the edge of farm fields, contours, and irrigation (chiefly water harvesting) (Kato et al., 2009) by top down approach system.

Since the early 1970s, following the disastrous drought and famine of the 1974/1975, soil degradation has been recognized as a serious problem in the highlands of Ethiopia (Mengistu et al., 2015) and established PAs, which were involved in mobilizing labor and assignment of local responsibilities (Bekele and Holden, 1998; USAID, 2000). Between 1976 and 1990, 71,000 ha of soil and stone bunds, 233,000 ha of hillside terraces for afforestation, 12,000 km of check dams in gullied lands, 390,000 ha of closed areas for natural regeneration, 448,000 ha of land planted with different tree species, and 526,425 ha of bench terrace interventions were completed (USAID, 2000) mainly through Food-for-Work (FFW) program incentives. Incentives like FFW have to be paid so that farmers build the conservation structures even in their own fields. Necessary repair and maintenance works are expected to be the responsibility of individual farmers (GTZ, 2002). The objective of the incentive emanate from the recognition that farmers do not have the necessary economic capacity to implement conservation measures, and therefore the FFW programs has been used to overcome the initial difficulties (Herweg, 1993).

Parallel to the soil conservation practices, integrating soil conservation research with crop production on different soil types was conducted, and the results confirmed that grass cover on soils could harness soil loss better than different cropping systems (Girma, 2001). Contour strip-cropping and buffer strip-cropping drastically reduced soil loss compared to continuous mono cropping.

However, adoption of soil and water conservation measures has been very limited. Knowledge among farmers about integrated soil conservation and water and nutrient management measures is very low (Girma, 2001); the emphasis has been largely on the construction of structural SWC measures in cultivated fields and afforestation of hillsides (Grepperud, 1996, Bewket, 2003). This massive campaign in soil conservation under FFW did not bring a wide dissemination and adoption of the practices by farmers. This is because farmers constructed SWC practices during the campaign, but they had no interest to implement or expand these without food for work (Shiferaw and Holden, 1998). Although, those achievements were later evaluated as only quantitative with minimal desirable outcomes and largely less
effective and often unsustainable (Admassie, 2000, Hengsdijk et al., 2005). Most of the conservation measures were removed after the government changed in 1991.

Between 1995 and 2009, for the second round promotion of soil conservation activities have been undertaken as part of the agricultural extension package of the present government through mass mobilization with a top down approach and without incentives for the time farmers spent on SWC activities. The approach was to construct conservation measures at individual level but not at watershed level. Emphasis was given to the quantity of measures rather than the quality of measures (Akalu et al., 2016). SWC is mainly limited to physical measures and dis-adoption and non-adoption of SWC measures were common phenomena in this period. This indicates that the extension system did not bring about behavioral changes among farmers probably because the focus was on changing the farmland rather than farmers’ behavior.

Again also the study conducted by (Akalu et al., 2016) indicated that since 2010, the government of Ethiopia has embarked again on a massive SWC campaign. The current approach is also mass mobilization, but then at watershed level. And there is an attempt to make such SWC program more participatory.

2.2.1. Method of soil and water conservation practices

The importance of planning soil-water conservation is to make up a system by selecting a set of individual items, which are relevant to the conditions and which can be combined into a workable system (Addisu, 2011). These conservation structures were introduced with the objectives of conserving, developing and rehabilitating degraded agricultural lands and increasing food security through increased food production availability (Adbcho, 1991). Even if different factors influencing the soil-water conservation practices, people across the world as well as in Ethiopia apply different methods of soil and water conservation according to their land characteristics, degradation extent, and technology available. Among those biological and mechanical soil and water conservation structures were the popularly practiced methods.

2.2.2. The Failure of soil and water conservation measures in Ethiopia

Studies conducted in different parts of the country come up with different factors that explain the low level of success of conservation initiatives. These studies attributed the low level of success of the initiative to different factors etc.

Institutional factors: During planning soil and water conservation intervention, top-down approach was pursued where government officials tell peasant association (kebele) what to do to get the food aid. This approach have local people little opportunities for discussion and participation on the initiative. The local people did not have a say on the design and their role was limited to provision of labor for the payment they get from the work. This made the local people see the initiative as imposition from the government and additional burden farmers are made to bear (Wood, 1990).

The conservation endeavor was linked to food-for-work payment. This made the conservation intervention to be concentrated in areas that are accessible. Hence, the coverage by the initiative was limited. This payment made farmers see the conservation measures belonging to the government rather than themselves. This in turn resulted, in poor quality of conservation structure constructed on farmlands. Very often, farmers destroy these structures to obtain additional food for maintaining destroyed structures (Woldeamlk, 2003).

Technological factors: Different conservation measure such as biological and agronomic conservation practices that could have potential to provide incentives for adaption have been over looked. In addition to this, these conservation measures have not been linked to indigenous conservation measure for which the local people are well-acquainted (Pretty and Shah, 1996).

Decrease in total cultivable area by the 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 (Kebede, 2014).
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% (Akalu Teshome et al., 2013). Literature of (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).

Social Factors: Personal characteristics of the household head like age, educational attainment, sex and family size were hypothesized to influence the decision to adopt conservation practices. The age of a farmer can enhance or prevent the retention of conservation structure. With age, a farmer may get experience about his/her farm and can react in favor of retention of structures. Exposure to education will increase the farmers’ management capacity and reflect a better understanding of the benefits and constraints of soil and water conservation. Education also increases the ability to obtain and apply relevant information concerning the use of soil and water conservation practices. Gender of farmer is also hypothesized to have an effect on adoption of conservation structures. Female headed or male-headed households can have different conservation behavior (Teshome et al., 2013).

Physical Factors: Farm size is often related to the wealth of a farmer and is expected to be positively associated with the decision to retain conservation structures. Farmers having larger farm size can afford to leave the structures while the small farmers cannot and tend to destroy the structures to allow them to produce more. Factors such as farm size, slope, and farm terrain, type of erosion, soil amendments, and location of farmland and land quality differentials were some physical factors which affect farmers’ ability to adopt soil and water conservation measure (John, 2008).

Attitudinal Factors: Perception of soil erosion and recognizing it as a problem is an important factor that influences the application of erosion controlling practices (Bekele and Holden, 1998). Thus, the perception variable is hypothesized to influence the retention of conservation structures positively. The role of perception of technology attributes in enhancing or eroding adoption decisions is well acknowledged. In this review of study, it is hypothesized that farmers’ expectation of the effectiveness of conservation structures in retaining soil from erosion were mostly a positive effect on retention soil-water conserving structures.

Economic Factors:
Off-farm employment generates income to the household and it may positively or negatively influence soil conservation. Off-farm income-generating activities compete for labor resource that the household uses as an input in conservation activities. Hence, those households that have off-farm income are less likely to engage in activities that conserve soil and water. On the other hand, off-farm income may ease the liquidity constraints needed for soil and water conservation investment or purchase of fertility enhancing inputs (Bekele and Holden, 1998).

2.3. Effects of SWC for Reclamation of Land Degradation and Climate Changes
The country is mainly linked to the prevailing degradation problem caused by continuous cultivation with limited amendment and wide spread use of dung and crop residue for household energy which substantially contribute to the loss of soil organic matter (Aklilu, 2006).

The soil and water that we use is integral to our livelihood. Most people know that they need clean air and clean water to health. Fewer people realize that their well-being also depends on the health of the soil. Soils and waters are supports the growth of most of our food and fiber; so, its productivity is a major factor in the overall development of all nations of the world. As part of development and modernization, trees are cut and vegetation is chopped off, leading to large-scale erosion (Addisu, 2011). According to (Sutcliffe, 1993) concluded that physical soil-water conservation activities are justifiable in moisture
stressed areas of Ethiopian highlands, where moisture conservation plays an important role in increasing yield. In parallel to this (Joyce, 1999) confirmed that the benefits of soil-water conservation in agriculture is proven and they offer small holders the opportunity to increase their productivity, safe guard, their land and reduce the risks of total crop failure in drought years.

2.3.1. Advantages of SWC in reducing soil loss and retaining moisture

The fundamental benefits 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 (Kebede, 2014). 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.

According to (Tesfaye, 2008) 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). 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 ton 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 channel and embankment of the physical SWC structures impound excess water 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 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).

2.3.2. 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 (Kebede, 2014). 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).

Literatures of (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 study by (Bekele, 2005) in the Hunde-Lafto area in eastern Ethiopia showed that SWC resulted in higher yields in unfavorable rainfall conditions.

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, (Kebede 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. Also 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%.

Report of (Nyssen et al., 2007) show 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). Literature review of (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).

In the central Kenyan highlands 82% of farmers perceived that SWC structures increased crop yields (Okoba and de Graaff, 2008). Yield across five different locations, Mesfin (2004) found that grain yields of maize produced under influence of fanya juu (29.8 q/ha), level bund (28.2q/ha) and graded bund (21.6q/ha) were higher by 9.2 q/ha (44.6%), 7.6 q/ha (36.4%) and 1.0 q/ha (5.1%) over the grain yield (20.6 q/ha) produced under the control plot respectively.

### 2.3.3. Physico-chemical properties of soil as affected by conservation measures

The impacts of the physical soil and water conservation measures can be classified into short- and long-term effects based on the time needed to become effective against soil erosion (Morgan, 1995). Accordingly, the short-term effects of stone bunds are the reduction of slope length and the creation of small retention basins for runoff and sediment. They therefore reduce the quantity and eroding capacity of the overland flow. These effects appear immediately after the construction of the stone bunds and reduce soil loss.

Evaluated the effects of structural land modifying measures on physical properties of soil and found higher content of silt and clay in terraced soil, which indicates that it has been least affected by erosion (Quraishi et al, 1977, 1980). Terraced lands have higher values of the total macro and micro water stable aggregates as compared to the unprotected land. Conserved soils had higher SOC concentration and SOC stock than soils without SWC. In general, SOC concentration increases with an increase in the application of crop residues to the soil (Girmay et al., 2008) because most agricultural crop residues are 40–50% C (Delgado et al., 2011). Zeleke et al. (2004) observed a 67% increase in SOC concentration in Andosols following 3 years of incorporation of maize (Zea mays L.) residues. The finding of (Dendooven et al., 2012) shows 1.5 times higher SOC concentration in the 0 to 20 cm layer of no tillage compared with conventional tillage where crop residue was retained and Arends & Casth (1994) reported that manure application in Hungary increased SOC concentration by 1.0–1.7%.

### 2.3.4. Effects of SWC measures on climate changes mitigation

Conservation agriculture as defined by the Food and Agriculture Organization of the United Nations (FAO, 2009), provides alternatives that can address not only some of the challenges posed by erosion, but also some of the challenges presented by climate change and requiring urgent action and different approaches of integrated conservation practices in the drylands and highland areas (FAO, 2014).

The FAO principles of conservation agriculture, including minimal disturbance of soils while providing continuous plant residue cover and using diverse rotations and/or cover crop systems, are also in sync with management options that can be used to sequester C and to help mitigate and adapt to climate change. Similar results was reported by (Silici, 2010) after working with small farmers from some region in Ethiopia, where conservation agriculture contributed to lower erosion, enhanced soil fertility, and
increased agricultural productivity. These results show that even for small farming systems with low inputs, conservation agriculture and management decisions that contribute to C sequestration, such as minimum soil disturbance, crop residue management, and crop rotation management, will help small farmers mitigate and adapt to climate change.

Soil management can be used to mitigate climate change because soils can sequester large quantities of atmospheric C across world agro ecosystems (Lal et al., 2011). Additionally, C sequestration could be an effective tool to help us adapt to climate change or extreme weather events. Sequestering C will increase SOM and water holding capacity, which can increase the likelihood of the crops being able to tolerate drier conditions, especially if drought-tolerant varieties are used, which could increase water storage in a future of expected higher air temperatures and evapotranspiration.

Nitrogen management by permanent vegetation can also be a key component in the mitigation of climate change because emissions of N₂O from the agricultural sector are significant (Lal, 2011). There is potential to use nitrification inhibitors, controlled-release fertilizers, and practices that help increase N use efficiency and reduce N inputs and net emissions of N₂O to mitigate climate change. Additionally, sequestering N and C in SOM and increasing N cycling, along with implanting other conservation practices, such as using cover crops or including a leguminous crop in the rotation, increases the potential for soils to cycle more N.

Conservation practices, the (Delgado et al., 2011) review of the literature shows that good policies that promote the implementation of conservation practices to mitigate and adapt to climate change will contribute to future food security, while a lack of good policies and/or the implementation of bad policies will not, and may even increase the negative impacts of climate change on limited soil and water resources. World croplands can sequester 0.02–0.76 Mg C ha⁻¹ y⁻¹ by adopting recommended management practices (Lal, 2001). Research by (Girmay et al., 2008) estimated the historical SOC sequestration potential of croplands in Ethiopia through adapting soil restorative measures at 215–638 Tg C over a period of 50 years.

3. CONCLUSION AND RECOMMENDATION

Land degradation and soil erosion are major threats to rural livelihoods in the highlands of Ethiopia, where population density is high and the bulk of crop production occurs. Integrated SWC interventions are required to systematically tackle these challenges. SWC delivers multiple social, economic, and ecological benefits including adaptation and mitigation of climate change. Literature shows that causes of land degradation were due to inappropriate land management, land scape, land use land cover and natural disasters that have been exaggerated by increment of human and livestock population. Thus these were results with soil and nutrient loss, climate change and brought food insecurity more than two to three times in the country.

From the reviewed literatures the government of Ethiopia have been promoting SWC measures to adopt for reducing soil erosion and land degradation after the 1975 famine in the country, but the system was top down approach and the focus was given only for quantitative structural measures rather than evaluating quality of the work by integral participatory approach. Most of the farmers’ perception on the presence and impacts of soil erosion and land degradation were no question, but the structures were not adopted accordingly due to: institutional, physical, attitude and social-economic factors of the time.

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 after so that the rate of adoption and its effects have been stated. Many cases studies indicated that biological measures and soil fertility management could improve effectiveness of the structure, soil fertility, and yield and biomass productivity (Zougmore et al., 2002; Adimassu et al., 2012). The improvement of soil quality had improved the soil water holding and nutrient retention capacity and crop and biomass productivity and significantly reduced runoff generation and soil erosion. As well the improvement in SOC stock contributes to the offsetting of anthropogenic GHG
emissions and the mitigation of climate change, while contributing to climate change adaptation through C sequestration and improved agronomic/biomass productivity.

Depending on the Reviewed of Literatures the Following Recommendations were stated:

a. 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.

b. The current motive and mobilization for SWC based participatory watershed management should be sustained and the strategy should be strengthened by national policies.

c. For better change, SWC 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.

d. For better dissemination and adoption of the measures awareness creation on the communities’ behavioral change should be sustainable through all stakeholders.

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