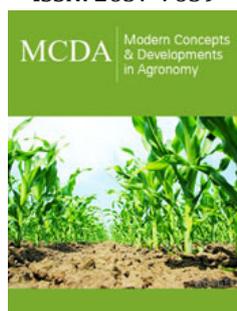


# Soil and Water Conservation Practices and its Contribution to Small Holder Farmers Livelihoods in Northwest Ethiopia: A Shifting Syndrome from Natural Resources Rich Areas

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## Abstract

Climate change is a current threat to food production and food security. Temperature rise and variability in rainfall patterns has had serious consequences on crop and livestock production in Ethiopia leading to a decline in food production. Climate Smart Agriculture (CSA) is the way to turn around the situation to more resilience and higher agricultural productivity leading to improved food security status. Although CSAs have been promoted in the country, not all farmers have adopted fully and their effects on food security are not clear. This review sought to evaluate the uptake of CSAs and their effects on food security among small scale farmers in Ethiopia. The demand for CSA practices was positively influenced by gender of the household head, household size, participation in off-farm employment, farm size, group membership, annual contacts with extension service agents, credit access and negatively influenced by age of the household head. The mean number of CSA strategies used by farmers was 2 applied by 44.8% of farmers. Most importantly, it was evident that CSA practices had a great potential to solve food security challenges. A complete package with crop management, field management, farm risk reduction and specific soil management practices had the highest implication to food security. To improve demand for CSAs, farmers need to be motivated to join and participate in farmer organizations through which they could gain access to extension information and credit. Additionally, farmers should be sensitized on the need to invest in farm productive assets in order to absorb the risks of climate change while also enabling them to benefit from use of CSAs which require these important assets. Finally, land fragmentation should be discouraged through civic education and provision of alternative income generating activities for farmers to benefit from CSAs when practiced on relatively bigger land.

**Keywords:** Climate change; CSA; Food security; Land fragmentation; Livelihood

**Abbreviations:** CC: Climate Change; COP: Conference of Parties; CSA: Climate Smart Agriculture; MCA: Environment Management Coordination Act; FACE: Free Air Carbon Enrichment; FARA: Forum for Agricultural Research in Africa; FAO: Food and Agriculture Organization; FICCF: Finance Innovation for Climate Change Fund; GHG: Green House Gas GOE Government of Ethiopia; HDDS: Household Dietary Diversity Score; ICRAF: International Centre for Research in Agro-forestry; IPCC: Intergovernmental Panel on Climate Change; NCCRS: National Climate Change Response Strategy; NEMA: National Environment Management Authority; PALWECO: Program for Agriculture and Livelihoods in Western Communities; SAPs: Sustainable Agricultural Practices; UNCED: United Nations Conference on Environment and Development; UNDP: United Nations Development Program; UNFCCC: United Nation Framework Convention on Climate Change; UNFPA: United Nations Population Fund

## Introduction

Current global developments call for more thoughtful management of the land. These developments include: the increased demand for land-based agricultural products for rapidly growing world population; the increasing scarcity of water, fuel, and minerals; the impacts of global climate change, increased commodity prices in the agricultural sector, and growing competition for land resources. Globally, large areas of land are being affected by land degradation, partly resulting from unsustainable land use. This is particularly the case in developing countries, which are especially vulnerable to overexploitation, inappropriate land use, and climate change. Bad land management, including overgrazing and inappropriate irrigation and deforestation practices often undermines productivity of land [1]. In the

context of productivity, land degradation results from a mismatch between land quality and land use [2]. Land degradation as a result is a biophysical process driven by socioeconomic and political causes [3]. Land degradation is related to climate and soil characteristics, but mainly to deforestation and inappropriate use and management of the natural resources, soil and water. It leads both to a non-sustainable agricultural production and to increased risks of catastrophic flooding, sedimentation, landslides, etc, and the effects of global climatic changes [4]. Hence, global climate change prediction, although still rather uncertain, will increase rainfall in some regions, while others might become drier, in a rather uneven spatial and time distribution.

This may contribute to accelerated land degradation processes leading to larger runoff and erosion, and to increased risks of flooding, landslides, mass movements and mud-flows in tropical regions, and to higher risks of crop production in subtropical and temperate regions [5]. The problems of soil and water degradation and derivative effects are increasing throughout the world, partially due to a lack of appropriate identification and evaluation of the degradation processes and of the relations causes-effects of soil degradation for each specific situation, and the generalized use of empirical approaches to select and apply soil and water conservation practices [5]. It has shown that soil and land degradation are the main factors attempting against the sustainability of agricultural production. Although land degradation is affected by soil and climate characteristics, it is mainly due to inappropriate use and management of the natural resources, soil and water, generally imposed by social and economic pressures. In addition to the negative effects on plant growth and on productivity and crop production risks, soil and land degradation processes may contribute, directly or indirectly to the degradation of hydrological catchments, affecting negatively the quantity and quality of water for the population and for irrigation or other uses in the lower lands of the watershed [5]. A study conducted in Ethiopia showed the standard estimates of soil loss in the country which were made to examine some of the principal environmental conditions and conservation practices that contribute to soil erosion in this country [6]. Soil loss was estimated by using the universal soil loss equation calibrated from field data collected on more than 19,000 fields. Seasonal soil losses ranged from 1t/ha (0.4ton/acre) to 143t/ha (63.8tons/acre); the average seasonal soil loss was 5t/ha (2.2tons/acre). Soil loss in Ethiopia showed a pattern of regional differences that closely followed variations in rainfall and topography. The development of regional strategies to minimize agricultural erosion is likely to be more effective than a single national policy [6]. The study carried out in different areas in Ethiopia showed that the effects of soil degradation and water shortages on crop productivity have induced researchers to introduce some innovative practices such as mulching, bunding, contour ridging, ripping, minimum tillage and others check the downward spiral in agricultural production. Varied soil and water conservation practices requiring varied farmer inputs have been promoted among farmers for over a decade now [7,8]. Proper land use, soil, water and crop management practices may make soil resistant against the

effects of climate changes and derived extreme events. Therefore, Sustainable Land Management (SLM) is required to minimize the issue of land degradation. Thus the SLM was defined by [1] as a form of land management that is targeted towards improving or stabilizing agricultural productivity, improving people's livelihoods and improving ecosystems.

### Smallholder farmers overview

Approximately 2.5 billion people live directly from agricultural production systems, either as full or part-time farmers, or as members of farming households that support farming activities [9]. In fact, there is no universally accepted definition of a small farm. According to IFAD [10] small farm may refer to the number of workers; capital invested, or amount of land worked. Land size is the criterion most commonly employed but given the differing potential of land in soil quality and rainfall, a single measurement hardly captures the sense of limited resources or relative powerlessness characteristic of smallholders. Overall, smallholder farmers are characterized by marginalization, in terms of accessibility, resources, information, technology, capital and assets, but there is great variation in the degree to which each of these applies. With these qualifications, the Food and Agriculture Organization of the United Nations (FAO) adopted a two hectare threshold as a broad measure of a small farm which is not inclusive of fishers and other small-scale food producers. In addition, smallholder farmers defined as those marginal and sub-marginal farm households that own or/and cultivate less than two hectares of land. On the other hand, according to the [11] there are 1.5 billion men and women farmers working on 404 million small-scale farms of less than two ha. However, the two hectares farm size is not a universal characteristic. Small holding sizes vary across regions from an average of 0.5 to 10ha and even 500ha are considered a smallholding in Australia [11]. Moreover, the definitions of this group vary according to the crop and context, and there are a wide variety of models of how smallholder farmers are integrated into global value chains [12]. The term "smallholder" is widely understood to include small farmers who do not own or control the land they farm and "out-growers" is used to refer to smallholders who are in a dependent managed relationship with an exporter [12]. Small holders include some 350 million indigenous peoples, who conserve many different crop varieties and livestock breeds. Their agricultural practices and techniques offer an important source of knowledge for the transition to sustainable agricultural intensification [10]. Women play a crucial role within the smallholder system and are commonly responsible for the production of food crops, especially where the farming system includes both food and cash crops [13] for an overview of gender in agricultural systems. The farm sizes vary between one and 22 acres, with an average size of 5acres what approximates 2 hectares.

### Smallholder farmers' perspective in Africa

In Africa, according to the study conducted by Dixon et al [14], smallholder farmers are categorized on the basis of the agro-ecological zones in which they operate; the type and composition of their farm portfolio and landholding; and/or on the basis of

annual revenue they generate from farming activities. In areas with high population densities, smallholder farmers usually cultivate less than one hectare of land, which may increase up to 10 ha or more in sparsely populated semi-arid areas, sometimes in combination with livestock of up to 10 animals [14]. Moreover, smallholder farmers are defined in various ways depending on the context, country and even ecological zone and in addition the term smallholder is interchangeably used with small-scale, resource poor and sometimes peasant farmer. Additionally, the term “smallholder farmers” has been defined by Adeleke et al. [15] as those farmers owning small-based plots of land on which they grow subsistence crops and one or two cash crops relying almost exclusively on family labour. And also, most smallholder operations occur in farming systems in the family at the center of planning, decision-making and implementation, operating within a network of relations at the community level. In fact, most African smallholder farmers defined on the basis of land and livestock holdings, cultivate less than 2 hectares of land and own only a few heads of livestock [15].

### **Smallholders farmers Benishangul Gumuz Region**

In case of settlers in Benishangul Gumuz region, most land is formed by very small holdings, primarily for household subsistence. The Central Statistical Agency (CSA) classifies Ethiopian farms into two major groups: smallholder farms (25.2ha). The majority of farmers in Ethiopia are smallholder farms, producing mostly for own consumption and generating only a small marketed surplus. Only 40 percent of the smallholders cultivate more than 0.90ha and these ‘medium-sized farms’ account for three-quarters of total area cultivated. Large farms (averaging 323 hectares per farm) are not widely spread in Ethiopia and the contribution of these farms to total agricultural output is limited. In 2007/08, smallholder farmers (12.8 million farmers) cultivated 12 million hectares of land or 96.3 percent of the total area cultivated. A total of 461,000 hectares was cultivated by large commercial farms. Smallholder farms generated 95 percent of total production for the main crops (cereals, pulses, oilseeds, vegetables, root crops, fruits, and cash crops). In contrast, large farms contributed to only 5 percent of total production of these main crops and to only 2.6 percent of cereal production in particular. An exception to this is the production of sugar cane, cotton, and other industrial crops, which are mostly-or only-produced by large farms (CSA data). Agricultural production patterns vary markedly across Ethiopia according to agro climatic conditions, in particular, widely varying rainfall and elevation. Agricultural researchers distinguish five agroecological regions in Ethiopia: moisture reliable cereal-based highlands, moisture reliable inset-based highlands, humid lowlands, drought prone highlands, and pastoralist area. Most smallholder farmers reside in the moisture reliable cereal-based highlands (i.e. 59 percent of total cultivated area). Farm area in the drought-prone highlands accounts for 26 percent of total area cultivated. With farmers using virtually no irrigation, reliable rainfall is an important condition to achieve good agricultural productivity.

However, in the moisture-reliable onset-based highlands (11 percent of total farm area) population pressure has diminished

farm size to such an extent that out-migration has become a major pathway out of poverty. Cultivation in the two other areas (humid lowlands and pastoralist area) is relatively less important, accounting for only 3.9% of all cultivated area in Ethiopia. Averaged over the period 2004/05–2007/08 cereals were grown on 73.4 percent of the total area cultivated, by a total of 11.2 million farmers. Together, these smallholders produce a yearly average of 12 million tons of cereals, which is 68 percent of total agricultural production. Pulses and oilseeds are the second and third crop, respectively, according to acreage. Although both the share in acreage and in production of coffee, chat, and vegetables. All cash crops are small, their significance is growing as the share of area cultivated increased by 12.3, 6.1, and 11.7 percent, respectively, per year from 2003/04 to 2008/09. Inset forms the staple crop in the moisture reliable inset based highlands. In 2008/09 it was produced on 2.5 percent of total area cultivated.

### **Role of smallholder farming in agricultural production**

Several studies have shown that smallholder agriculture has a greater role in global agricultural production. For example: China, has close to 200 million smallholdings, and according to Dan [16], it has at least 250 million small family farms [16]; they cover only 10 percent of the total amount of agricultural land that is globally available, and they produce 20 percent of all food in the world [16]. This is an important indication of the productivity that might be achieved in smallholder agriculture. In Brazil, 58 percent of all milk is produced by household agriculture ([www.saladeimprensa.ibge.gov.br](http://www.saladeimprensa.ibge.gov.br)), for chicken and pork this is respectively 50 percent and 59 percent. For coffee, the contribution of smallholders is 38 percent, for maize 46 percent, for beans, the contribution of smallholders reaches 70 percent and for cassava this is as high as 87 percent ([www.ibge.gov.br](http://www.ibge.gov.br)). In Benin, the traditional sector, consisting of small-scale family-run units, provides 80 percent of the production of palm oil. This craft industry has always been able to adapt to changes in the upstream sector (variations in the volumes of raw materials offered by planters) and downstream (changes in demand) and covers most of the local market. New techniques have secured the stability of the sector. For palm oil, similar situations can be found in Nigeria and other West and Central African countries. Other products can also be mentioned, in so many ways, by craft industries often run by women: making farinha out of cassava in Brazil, or Tempe from soybeans in Indonesia [17], with tens of thousands of production units. Smallholder agriculture plays a major role in the national economy of many countries, particularly in least developed countries. This has been shown by Delgado [18] who affirms that smallholding farming in sub-Saharan Africa (SSA) is thought at present to account for 70 percent of total employment, 40 percent of total merchandise exports, and 33 percent of GDP on average, although the shares are much higher in many countries of the region. One-third to two-thirds of value added in manufacturing depend on the supply of agricultural raw material, mostly from smallholders. Furthermore, a primary agricultural commodities account for large shares of total merchandise exports in the region, again, mostly from smallholders despite these achievements,

economic conditions for a smallholders in SSA have been especially tough.

Some studies done in Ethiopia have found that farmers who sell coffee cherries to wash stations increase their annual expenditures by 17 percent compared with farmers who sell lower-quality parchment coffee [19]. The same study indicates that since the reform, coffee farmers have increased their food consumption and their overall household expenditures, leading to improved food security and to generally improve economic conditions for coffee smallholder farmers. Again, in a survey of 239 farmers and coffee-washing station workers, [20] asked farmers to identify the benefits they received as a result of being a member of a coffee cooperative. Farmers listed a number of direct financial benefits, such as increased prices received for their cherries, employment opportunities and better and easier access to loans, particularly access to credit to purchase inputs such as fertilizers. Farmers also noted that their families are now better fed, that they are able to hire laborers, that they have helped with marketing and sales, and that they receive some medicines for free. And they stated that they benefit from socializing with and learning from others, this means they have increased or improved their experiences.

### Land and soil degradation

**Globally:** Land degradation remains a major threat to the world's ability to meet the growing demand for food and other environmental services. It is complex and involves the interaction of changes in the physical, chemical and biological properties of the soil and vegetation. The complexity of land degradation means that its definition differs from area to area, depending on the subject to be emphasized. Land degradation is a gradual negative environmental process which can be accelerated by human activities. The negative effects generally touch on food security, economic wellbeing, and environmental conditions; thus explaining the reason behind much attention given to land degradation worldwide [21]. Forms of degradation vary with the causative factors: loss of topsoil, terrain deformation mass movement or water and wind erosion, loss of nutrient and organic matter, salinization, alkalization, acidification, pollution (chemical deforestation, compacting, crusting waterlogging substance of organic soils (physical deterioration) of the total degraded area, overgrazing, agricultural mismanagement, deforestation and over exploitation of natural resources are said to account respectively for 49,24,14, and 13 percent [21-23]. Farmland degradation can also have important negative effects of the farm, including deposition of eroded soil in streams or behind dams, contaminations of drinking water by agrochemicals and loss of habitat [21]. Various sources suggest that 5 to 10 million hectares are being lost annually to severe degradation. If this trend continues, 1.4 to 2.8 percent of total cropland, pasture and forest land will have been lost by 2020 [21]. And as stated once more by IFPRI [21] that, by the year 2020, land degradation may pose a serious threat to food production and rural livelihoods, particularly in poor and densely populated areas of the developing world. Human induced soil degradation affects around 1.035 million hectares. Of this total: 45 percent is affected by water erosion, 42 percent by wind erosion, 10 percent by chemical deterioration and

3 percent by physical deterioration of the soil structure. As shown by these percentages, water erosion is the most dominant form of degradation and wind erosion in the developing world. The later one is dominant in arid zones. The largest area affected is in Asia and Pacific, with about 550 million hectares. In Africa, an estimated 500 million hectares of land have undergone soil degradation since 1950, including 65% of the regions agricultural land. The main direct drivers (pressures) contributing to land degradation in sub Saharan Africa (SSA) are non-sustainable agriculture, overgrazing by livestock, and overexploitation of forests and woodlands.

The need to produce more food for the rapidly increasing human population has led to the rapid expansion of agricultural land and the shortening of the fallow periods in traditional, extensive land-use systems, which have reduced the regeneration of soil fertility through natural processes [24]. Today, close to 33% of the earth's land surface is devoted to pasture or cropland. Land degradation affects about 300 million hectares of land in Latin America while in North America; about 95 million hectares are affected as well as in Europe, 157 million hectares affected by water and wind erosion alone. The research again shows that the land degradation is a global issue that the world of today is facing with. For example, in China alone, between 1917 and 1990, the area of arable land was reduced by an area equal to all the crop land in Denmark, France, Germany and The Netherlands combined mainly because of land degradation. Much of the recent increase in area under agricultural land continues to occur mostly in developing countries, mainly Africa and Latin America [25].

**The status of land degradation in Africa:** Nearly one thousand million hectares of vegetated land in developing countries are subjected to various forms of degradation, resulting in moderate or severe decline in productivity. About 490 million hectares in Africa are affected by different types of degradation from the approximately 2976 million hectare total land area in Africa. Of this total land, 72 percent are problem of soil with different production constraints such as soil acidity, low fertility, saline and poorly drained soils. Poor and inappropriate soil management is the main cause of physical and chemical degradation of cultivated land [26]. Sub-Saharan Africa (SSA) is particularly vulnerable to threats of natural resource degradation and poverty. This is due to various factors, including a high population growth rate and increasing population pressure, the reliance on agriculture that is vulnerable to environmental change, fragile natural resources and ecosystems, high rates of erosion and land degradation, and both low yields and high post-harvest yield losses. On top of this can be added sensitivity to climate variability and long-term climate change [27]. High population growth and migration in response to the shortage of land resources are important factors contributing to the degradation of agricultural land in SSA population continue to grow at higher rates than any other region of the world (3 percent per year) [28]. FAO estimates of the actual supporting capacity of land range from 10 to 500 persons per square kilometers. From 37 countries in Sub-Saharan Africa (SSA), confirmed a significant relationship between population pressure, reduced fallows and soil nutrient depletion. This indicates a generally unsustainable

nexus between population, agriculture and environment that leads through a downward spiral into a poverty trap [28]. Degradation was found to be increasing in most sites, primarily caused by inappropriate soil management.

In some way, land degradation appeared to be caused most frequently by population pressure, insecure land tenure, and poverty in combination with aspects of governance, institutional functioning, and politics [1]. For example, in Somalia, land degradation is under three groups of types: soil degradation, biological degradation and water degradation. Soil degradation occurs when the soil chemicals or physical conditions have been altered. While biological degradation includes loss of biomass, biodiversity and loss of soil life. The most common types in Somalia, loss of vegetation cover, loss of vegetation species, loss of habitat and reduction of biomass [21]. In Kenya, classification of Landsat imagery for the period 1973, 1988 and 2003 showed that there were significant changes in land use, land cover (LULC) in the western Kenya districts in the area under agricultural activities, increasing from 28 percent in 1973 to 70 percent in 2003 while those under wooded grassland decreasing from 51 percent to 11 percent over the same period. Detailed field observation and measurements showed that over 55 percent of the farms sampled lacked any form of soil and water conservation technologies. Sheet erosion was the most dominant form of soil loss observed in over 70 percent of the farms. There was a wide variability in soil chemical properties across the study area with values of most major properties being below the critical thresholds needed to support crop production. Notable was the high proportion, 90 percent of farms with slightly acidic to strongly acidic (pH 5.5) soils. Over 55% of the farms had less than 2 percent soil organic carbon. In Sub-Saharan Africa (SSA) concerted efforts to deal with land degradation through SLM must address water scarcity, soil fertility, organic matter and biodiversity. SLM seeks to increase production through both traditional and innovative systems, and to improve resilience to the various environmental threats [27].

**The case of land degradation and land use policy in Ethiopia:** The increase in degradation processes acting on hill slopes eventually lead to excessive deposition in the valley bottoms, conditions which, over time, can precipitate flood damage and the destruction of lowland crops. Decreasing soil fertility, for example, reduces vegetation cover which, in turn, increases the potential for soil loss and even lower fertility. The study conducted by Clay & Lewis [29] showed that farmers themselves said that the productivity of the land is declining and that often this is due to soil erosion. Farmers have observed a decline over time in the productivity of a full 50 percent of their holdings. Two reasons for the declining productivity of the farmers' farms focus on: over-cultivation and soil erosion. This study also stated that near half 48.7 percent of the fields identified as declining in productivity are believed by their operators to be over-cultivated- undoubtedly, to the gradually disappearing use of fallow periods in the crop rotation cycle. Secondly, only to over-cultivation as a perceived cause of declining productivity is soil erosion.

The conservation of scarce land resource is essential to the long-term viability of agriculture in Ethiopia. High population density, steep slope abundant rainfalls prevail in the highland portions of this country, making the task of erosion control uncommonly difficult for the farmers. And over 90 percent of all households draw their livelihood from agriculture. Population pressure in Rwanda has pushed farmers onto increasingly fragile lands. Without proper attention, the downward spiral of environmental deterioration in affected areas will be inevitable. In the northwest region, where the potential for agricultural productivity is high, the expansion of agriculture onto marginal lands is already resulting in serious slope failures (slumps and landslides) [30]. A UN Food and Agriculture Organization (FAO) study in 2006 noted that the country faces moderate to severe soil erosion on 50 percent of its land surface. MINAGRI has attempted to address this problem through a program of soil erosion protection. Similar to other countries in East Africa, unpredictable rainy seasons, prolonged droughts, flood and landslides create added challenges [31].

With these challenges occur in Ethiopian agriculture, the government has introduced the program of Land Consolidation. Land consolidation, however, is generally considered as putting together small plots with the aim of making them viable and more productive per unit of investment, through economies of scale. These need not change the amount of land controlled by individuals and is therefore not necessarily an instrument for social justice [32]. Land consolidation is not a new concept and has been implemented in different a number of countries. One study has shown that it is believed that land consolidation was practiced around 1060 B.C. in China and 300 B.C. during the Roman Empire. And land consolidation was in practice in Europe since the Middle Ages and the current practices date back to the 19th and 20th centuries [33]. Practices of land consolidation are found today in Germany, the Netherlands, France, Belgium, Luxembourg, Austria and Switzerland, as well as Finland, Norway, and Sweden. There has been considerable land consolidation in Eastern European countries after the reform of socialist production systems that had resulted in fragmented property rights. In the whole of Western Europe by early 1990s land consolidation involved a quarter of all cultivated land, which is in excess of 38 million hectares of agricultural land [33].

**Impact of global land degradation on agricultural production:** Globally, there are few studies of the impacts of degradation on agricultural production. An analysis of results of GLASOD [21], has shown that there has been a 17 percent cumulative productivity less over 45 years as a result of degradation. During that same period, growth in global food production and long-term declines in grain prices were unprecedented, clearly other factors offset the effects of degradation on aggregate performance. A study of the impact in Africa based on field data estimated that yield reductions due to past erosion may range from 2 percent to 40 percent with a means of 8.2 percent for the continent and 6.2 percent for sub Saharan Africa. If the accelerated erosion continues unabated, yield reduction by the year 2020 may be 16.5 percent

for the continent and 14.5 percent for sub Saharan Africa. Evidence from four Southeast Asians and three Middle Eastern countries indicates a degradation induced decline in productivity, greater than 20 percent [21]. Removal of a 5cm layer of topsoil has a greater impact on a poor shallow soil than on a deep fertile soil. Therefore, relative changes of the soil properties are better indicators of soil degradation: the percentage of the total top soil lost, the percentage of total nutrients and organic matter lost, the relative decrease in soil moisture holding capacity, changes in buffering capacity, etc [34].

**Soil and water conservation as an adaptation to climate change by farmers in Ethiopia:** In 2015, 14,000 rural families suffered from the impact of natural disasters in the Benishangul Gumuz Region. These natural disasters damaged agricultural production due to hail, frost, droughts and river floods. Several international institutions like IPCC [35,36], Oxfam [37], FAO [38] and United Nations [39] relate these effects of extreme weather conditions to climate change. In combination with unsustainable land management practices, the whole region in Ethiopia became prone to land degradation over the past decades. Soil erosion, loss of vegetation and decline in crop production were problematic for farmers living in this area [40]. This made adaptation to a changing climate difficult for farmers in a country which has "the highest percentage of people living in poverty in Ethiopia, with approximately 60 per cent below the national poverty line, a share which rises up to 75% in rural areas" [10,41]. Therefore, participative projects are helpful in motivating farmers to invest in Soil and Water Conservation (SWC) to stop soil erosion and use water more efficiently [40].

### Soil and water conservation technologies

**Sustainable land management:** Like other composite approaches to agricultural development, soil and water conservation (SWC) has numerous definitions. Over time the conception of SWC has changed from an initial emphasis on structures to reverse soil erosion to an important part of sustainable land management. UN Summit (1992) and WOCAT have defined Sustainable Land Management (SLM) as the use of land resources, including soils, water, animals and plants, for the production of goods to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and the maintenance of their environmental functions. At the same time as, Terr Africa partnership (2005) has further defined sustainable land management as the adoption of land use systems that, through appropriate management practices, enables land users to maximize the economic and social benefits from the land while maintaining or enhancing the ecological support functions of the land resources [13]. Sustainable Land Management (SLM) is crucial to minimizing land degradation, rehabilitating degraded areas and ensuring the optimal use of land resources for the benefit of present and future generations. Sustainable Land Management has also an objective of promoting human coexistence with nature with a long-term perspective so that the provisioning, regulating, cultural and supporting services of ecosystems are ensured. SLM is an essential prerequisite to sustainable development; progress should be

made simultaneously at all levels. In terms of such concerns as food security, poverty alleviation, livelihood improvements, water conflicts and ecosystem services, SLM are an important local issue that is also a global concern.

**Sustainable land management technologies:** The study done by [1] found that combinations of SLM measures appeared to perform better than applying one type of measure by itself. The study highlighted thirty-eight SLM measures including; thirty for SLM technologies and eight for SLM approaches. The physical practices used in the field to control land degradation and enhance productivity. The SLM technologies, in other words could be divided into five groups: cropping management, water management, cross-slope barriers, grazing land management, and forest management. They addressed all the main types of land degradation and depending on the kind of degradation addressed, agronomic, vegetative, structural, or management measures were used, or some combination of these [1]. Most of the technologies aimed to prevent or mitigate degradation; only a few were described as intended for rehabilitation. These are the physical practices in the field that control land degradation and enhance productivity in the field. They are: Agronomic (e.g. intercropping, contour cultivation, mulching), Vegetative (e.g. tree planting, hedge barriers, grass strips), Structural (e.g. graded banks or bunds, level bench terrace), Management measures (e.g. land use change, area closure, rotational grazing).

Combinations of above measures which are complementary and thus enhance each other are part of a technology. According to WOCAT [42], four different conservation measures types exist: Agronomic, vegetative, structural and management measures. Agronomic measures include soil management, such as contour cultivation, direct planting, soil cover, crop mixtures and rotations. These measures are normally cheap but very effective. Manuring and composting also belong to these measures and have a big influence on soil fertility. Agronomic measures are normally linked with annual crops and repeated every year or cropping season. Usually, they are not permanent and do not change the slope profile. Vegetative measures such as grass strips, hedges, windbreakers or agro-forestry help to protect the ground and reduce the wind speed. These measures are of long duration and often causing a change in slope. Water competition between crops and the plants of the vegetative measures can cause problems if water is short. Special management is needed to reduce this competition. Terraces, bunds and banks are the structural measures. In most of the cases, they are built to prevent movement of eroded soil. The construction of such measures is related to earth movement and leads thereby to changes in slope profile. Structural measures require a considerable input for implementation and maintenance in terms of money and labor. Management measures involve a fundamental change in land management. They are often applied where degradation is much advanced and other conservation measures would not be useful until a land use change is accomplished. Such changes can take place, for example, in overgrazed areas. Uncontrolled grazing is stopped and the vegetation gets the possibility to recover. These changes in management are often not related to great costs, but in

certain circumstances, the conservation of one part can increase the pressure in other areas. A combination of the measures described above is often applied by land users.

#### Soil and water conservation technologies used in Ethiopia:

As described by REMA [43], the soil and water conservation measures used are for sloping land in order to sustain agriculture and Agroforestry production. There are various measures and application of soil and water conservation used in the whole country. However, with population pressure on mountain areas showing no signs of diminishing, it is becoming increasingly clear that watershed protection is vital to increase upland production while providing the necessary protection. Watershed rehabilitation generally requires land use adjustment measures which contribute to a reduction in soil erosion rates, and at the same time increase rural employment and income. The three main techniques considered are agronomic or biological measures, soil management strategies and mechanical or physical methods. Suggested measures in these on farm erosion control strategies are: Agronomic or biological measures utilize the role of vegetation in helping to minimize erosion. Soil management is concerned with ways of preparing the soil to promote dense vegetation growth and improve its structure so that it is more resistant to erosion. Mechanical or physical methods depend upon manipulating the surface topography, for example, by installing terraces to control the flow of water. Mechanical measures are largely ineffective on their own because they cannot prevent detachment of soil particles. Their main role is in supplementing agronomic measures, being used to

control the flow of any excess water that arises [43]. Mechanical methods, including bunds, terraces, waterways, and structures such as vegetative barriers or stone lines installed on farm also can break the force of winds or decrease the velocity of runoff to reduce soil erosion. In general, when deciding what conservation measures to employ, preference is always given to agronomic treatment. These are usually less expensive and deal directly with reducing raindrop impact, increasing infiltration, reducing runoff volumes and decreasing water velocities while mechanical measures are effective soil conservation technologies as they reduce soil loss [43]. The most soils and water conservation used in Ethiopia are presented in Table 1. Various studies done in Ethiopia are based on dissemination of soil and water conservation technologies, cost-benefits of terraces and the role of the Agroforestry system in improving soil properties especially on steep slopes of the country. One research conducted in Ethiopia has shown that the use of living hedges has greatly improved the soil properties where after 2 years, living hedges reduced runoff to less than 2 percent and erosion, they produced fire wood and high quality leguminous forage and returns to the soil as much as 80 to 120kg/ha/year of nitrogen, 3kg/ha/year of phosphorus, 30 to 60 kg/ha/year of calcium and potassium, 10 to 20kg/ha/year of magnesium [44]. Again, findings of a study based on soil and water conservation investments in Ethiopia showed that 76.2 percent of farm holdings have received investments in the form of radical terraces, hedgerows, grass strips, or anti-erosion ditches, and that such investments are concentrated on the steeper slopes [45].

**Table 1:** Major soil and water conservation measures used in Ethiopia.

Agronomic or Biological Measures	Soil Management Strategies	Mechanical or Physical Method
Mulching	Conservation Tillage	Terracing
Crop Management	-Minimum tillage	Contour Bunds
-Cover crops	-Improved tillage	Infiltration Galleries
-Improved fallows	-No-till	Waterways
-Intercropping	Contour tillage	Gully Controls
-Planting Pattern/Time	Strip farming	-Stabilization structures
-Crop rotation		-Stone check dam
Agroforestry		-Gabion Baskets
		-Reno Mattresses
		-Stone lining

Source: Ethiopia Environmental Protection Authority (EEPA) 2010.

**SWC technologies in Benishangul Gumuz Regional state (BGRS):** The land in the study area is very shallow and susceptible to high soil erosion. They are using organic fertilizers, terraces, normally, the LWH and government have helped the farmers by providing them training on how to make the land more productive by shifting from substance farming system to the agricultural market-oriented system, which will help farmers to develop themselves and getting high yields of agricultural productivity.

Different studies done on SLM and CSA in BGRS: Various studies have been done on Sustainable Land Management. The

study carried out in Benishangul Gumuz Regional State, Ethiopia showed that farmers highlighted some reasons for adopting Conservation Agriculture, including economic factors such as crop protection, human factors such labor and natural factors such as soil conditions. Furthermore, in this study, farmers have also given other reasons indicating that there are two important elements for adoption of CSA; first of all, farmers have to be aware of their situation and recognize that runoff, soil erosion, high evaporation losses and other factors reduce the productivity of their farms. Secondly, farmers have to be informed about the possibilities of

CSA and experience the advantages of the technologies on their own, for example on field visits. And also, farmers have said that CSA is cheap and less labor intensive. Additionally, according to the research conducted by Simon et al. [46] & Alufah et al. [47] household size, perception of the soil erosion problem, training in soil erosion control, land ownership and access to institutional credit had significant effects on the adoption of SWC technologies. A research conducted by Toborn [48] showed that size of farm holding is a surrogate for many potentially important factors such as access to credit, capacity to bear risk, access to scarce inputs (water, seeds, fertilizers, insecticides), wealth, access to information, and so on. Since the influence of these factors varies in different areas and over time, so does the relationship between holding size and adoption behavior. One more study revealed that age, distance of farm, slope of cultivated land and membership of an organization or group has a positive influence on the adoption of SWC technologies. On other hand the analysis of the interviews during the research indicated that factors that have to take into consideration in order to increase the rate of adoption: first, non-CSA farmers have to realize that runoff, soil erosion and high evaporation losses reduce the productivity of the farms, secondly, farmers have to be aware of the advantages related to CSA technologies and third, farmers have to be attended and supported during the phase of adoption [49] while according to Simon et al. [46] & Alufah et al. [47]; education, distance of farm from homestead and number of farm parcels have negative effect on adoption of SWC technologies in the catchment.

It was clear from the literature that farmers consider personal characteristics, socioeconomic, institutional, technology attributes and other exogenous factors before adopting SWC technologies in the catchment. The findings of the study reinforce the fact that in order to achieve sustainable watershed management, institutional and economic factors should be given special attention [46]. As revealed by Toborn [48] FAO has published the criteria used to explain adoption of SWC technologies, including

- A. Farmer and farm household characteristics,
- B. Farmer biophysical characteristics,
- C. Farm financial/ management characteristics, and
- D. Exogenous factors. During the study conducted in Kenya by Alufah et al. [47] terracing, tree planting, agroforestry, cover cropping, mixed cropping and contour vegetation strip were major SWC technologies in the area.

An important point found during one research conducted by [50], is that a mixed picture where plots without SWC generally have higher yield values per hectare. These plots with SWC however, are significantly steeper and more eroded than plots without SWC. And also an additional research has shown that comparing SWC technologies to plots without SWC indicated that SWC increased the returns from degraded plots and sometimes from other inputs [51]. Soil erosion and shortage of drinking water have been identified as serious problems of the community and farmers lose more than 2 hours per day to fetch water [50].

And according to the findings of a research done by Gebreselassie et al. [52], showed that the cause of soil erosion

were identified as the nature of the topography, high and erratic rainfall patterns, extensive deforestation, continuous cultivation and complete removal of crop residues from the field, overgrazing and free-grazing, improper farming practices and development efforts, overpopulation and poverty, socioeconomic problems, lack of awareness on the effect of erosion, and poor land use policy enforcement. Further, these findings of Gebreselassie et al. [52] also confirmed that soil bunds stabilized with vegetative measures are better held the soil in-situ and improve inter-terrace soil physical and chemical properties compared to the non-conserved fields. Additionally, the results of the experiment in this study indicated that organic carbon (OC), total nitrogen (N), bulk density, infiltration rate, bund height, and inter-terrace slope are significantly affected by soil conservation measures. The non-conserved fields had a significantly lower organic carbon, total nitrogen, and infiltration rate; whereas higher bulk density as compared to the conserved fields with different conservation measures. However, no significant differences in bulk density were observed among the conservation methods Gebreselassie et al. [52].

Furthermore, another research conducted in Ethiopia by Yenealem et al. [53] indicates that on average participant households earned 8.3 percent more crop production value per hectare and 21.2 percent more gross household income than their matches. Therefore, in agricultural dependent countries, soil and water conservation is crucial in improving the livelihoods of the rural farm households. The appraisal study by Keyser & Mwanza [54] conducted in Mumbwa, Zambia, noted differential income for the user of conservation farming techniques in the order of 45-60 percent over and above the users of conventional farming. The article, reviews of adoption of conservation technologies in Sub-Saharan Africa undertaken by Haggblade et al. [8] also recognize the likely potential in financial incentives of soil conservation practices. Smallholder farmers in the micro-catchment who adopts SWC technologies attain higher productivity. Knowler & Bradshaw [55] draw interesting conclusions from a review and synthesis of recent research on conservation agriculture. Based on 130 financial analyses of conservation agriculture and other soil and water conservation in Sub-Saharan Africa and Latin America/Caribbean, the authors conclude that the former produced positive net present value in 90 percent of the cases, the latter in 58 percent of the cases. Since the adoption of SWC is still low with some notable exceptions, what other factors are at play when farm finance impact seems positive.

## Conclusion

SWC around the world has gained a lot of attention and a variety of SWC practices has been hypothesized to contribute to food security, adaptation and mitigation. The results indicate that adoption rate of SWC was still low with crop management practices being the most dominant perhaps to meet food production for subsistence. The findings indicate that specific soil management and improved livestock management practices were less adopted. The likelihood of higher demand for SWC strategies was positively influenced by gender of the household head, household size, participation in off-farm employment, farm size, and membership to a group, number of annual contacts with extension service

agents, and credit access and age of the household head. This observation provides a wider spectrum of interventions to improve the demand for SWC. Soil and water conservation activities in the region have the potential to alleviate food insecurity among small scale farmers if used in combinations and to a larger extent. Thus in conclusion, improved adoption of these practices could help reduce food insecurity for small scale farmers.

## Recommendations

To improve the demand for SWC practices, farmers should be motivated to join and participate in farmer organizations so that they could share farming information. Further, farmers could also stand a chance to be linked conveniently with extension service providers and farm financing agents. Crucially, off-farm income improves farm liquidity which provides an alternative means of financing farm operations. Thus, the County and national government together with development partners should invest in important infrastructure like electricity and roads which could spur rural based economic activities making it easier for farmers to engage in off-farm income generating activities. Finally, farmers should be encouraged to incorporate all SWC technologies as much as possible to have a higher effect on food security status. Also, farmers should be sensitized on the need to invest in productive farm assets to enable them absorb risks associated with climate change at the same time enhancing their ability to uptake important SWC practices. The sensitization could be done in groups by extension service providers. Land fragmentation should also be discouraged through civic education and engagement in alternative income generating activities for farmers to benefit more from SWC when practiced on relatively bigger portions of land.

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