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The Successful Soil Conservation Methods in Ethiopia: A Review

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Abstract: Soil conservation is the protection of fertile top soil from erosion by wind and water and the replacement of nutrient in the soil and it is the combination of the appropriate land use and a management practice that promotes the productive and sustainable use of erosion and other forms of land degradation. It has become an integral part of land use and receives support within a social and economic environment which is conductive to the maintenance and improvement of soil capital. The grass strips, bench terraces and fanyajuu reduced soil loss by 40, 76 and 88%, respectively, compared to the land without those structures. In the Anjeni area of Ethiopia, graded soil bund reduced soil loss by 40% as compared with untreated plots. An annual soil loss from crop lands with level soil bunds reduced by 51% when compared to the control plot. In DebreMewi, Ethiopia, Stone bunds and soil bund reduced soil loss by 72.9 and 83.7% respectively as compared to non-treated land. In northern Ethiopia, especially in Tigray, Stone bund is effective in reducing soil loss by 68% particularly at its early age. In the central highlands of Ethiopia, the soil bund reduced the yield of barley by 7% when the spaces occupied by the structures are taken into account and otherwise increased yield by 1.7%.Agro-forestry is also one of the practices mainly used in Ethiopia at the low land areas where Mango (*Mangifera indica* L.) is well integrated with the cultivated crops and considered as an important component of the farm. The vetiver system reduces soil loss from farm land by 90% and reduces rainfall runoff by 70%. Rotating the major cereals, after legumes or oil a crop is mainly used for soil fertility maintenance, weed and disease control. Generally, Practicing indigenous and introduced soil and water conservation practices to either divert runoff into safe channels, or reduce it by promoting infiltration is the ultimate aim of soil conservation to obtain the maximum sustained level of production for a given area of land whilst maintaining soil loss below a threshold level which, theoretically, permits the natural rate of soil formation to keep pace with the rate of soil erosion.

Key words: Agroforestry · Conservation · Erosion · Soil Bund · Soil · Stone Bund · Terrace

INTRODUCTION

Agriculture is the main sector of the Ethiopian economy and contributes approximately 42% to the gross domestic product (GDP) and employs over 80% of the population [1-3]. Despite its role, agricultural production is constrained by high climate variability where rainfall distribution is extremely uneven both spatially and temporally and this has negative implications for the livelihoods of people [4]. Drought frequently results in crop failure, while high rainfall intensities result in low infiltration and high runoff causing enhanced soil erosion and land degradation. The combination of the rapid growing world's population, slow economic growth and limited extent of natural resources, especially in many developing nations like Ethiopia has resulted in the un sustainability use of natural resources [5]. Soil is one of fundamental natural resources to support life on earth. Soil is finite and non-renewable natural resource which takes between 200 and 1000 years for 2.5 cm of topsoil formation under cropland condition [6]

As a core component of land resources, soil is the source of many ecosystem services essential to humans and the environment [7]. It is the base to support primary production through organic matter and nutrient cycling, control of pests and diseases; decontamination of the environment and provision of ecosystem services [8]. Soil also plays a major role in global climate processes through regulation of carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4) emissions [9]. Global estimates,

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however, indicate that human pressures on soil resources are reaching critical limits [9] and soil is becoming vulnerable to various forms of depletions, such as soil erosion, soil fertility decline and associated changes in soil physical and chemical properties. Soil erosion by water is the most severe and widespread that occupies 56% [10].

The average annual rate of soil loss in Ethiopia is estimated to be 12 tons/hectare/year and can be even higher on steep slopes (greater than 300 tons/hectare/year or about 250 mm/year) where vegetation cover is scant [11]. Alemayehu [12] also reported the same result. Soil erosion is very severe problem in highlands of Ethiopia, especially on cultivated fields of northern and central high lands of Ethiopia and erosion on cultivated lands averagely estimates 42 tons per hectare per year on currently cultivated lands [13].

According to Tegegn [14], Soil Erosion is the removal of top soil faster than the soil forming process to replaces it, due to natural, animals and human activities: overgrazing, over cultivation, forest clearing and mechanized farming. As a result, soil erosion is the most immediate environmental problem facing the nation at present time. Soil erosion, principally caused by over grazing, continuous cultivation, deforestation and remove of crop residue from the field, highly undermines the role of agriculture to alleviate poverty and food insecurity in whole parts of Ethiopia. The estimated annual soil loss in Ethiopia due to erosion is 1.5 billion tons, of which 50% occurs in cropland [15]. This is very serious problem compared to the estimated soil formation rate of less than 2t/ha/year [16]. Its severity is being pronounced in the Northern highland areas of the country [17, 18] which has been characterized by steep slopes, intensive rainfall, sparse vegetation, high population and livestock densities [19].

It is clear that soils with low fertility are unable to allow sufficient crop cover to sustain life. Erosion and low humus content of such soil decrease infiltration and moisture holding capacity of the soil. These all quest for the importance of soil conservation measures. Thus, it is increasingly recognized that adequate conservation of soil resources is a precondition for sustainable rural development strategies particularly in the highlands of Ethiopia [20]. A large number of conservation, rehabilitation and afforestation campaigns were undertaken through Food-For-Work (FFW) programs. Nevertheless, most efforts of soil conservations have not been widespread and didn't bring signi?cant changes as expected [21, 22]. Effective protection and conservation of SWC can be realized only when farmers accept and deicide on the benefits of SWC technologies and actively involved in the implementation and maintenance processes [23]. The decisions of farmers to use and manage natural resources highly depend on their perception of the landscape [15]. Indeed, farmers can modify the technologies to their own real situations [22].

And threats not only to agricultural production but also to the economy, as the countries' economies depend on agricultures. Soil erosion creates sever limitations to sustainable agricultural land uses, as it reduces on farm soil productivity and cause food insecurity [24]. Erosion results in the degradation of soil productivity in a number of ways. It reduces the efficiency of plant nutrients use, damages seeding, decreases plants roots depth, reduces the soil water holding Capacity, decreases its permeability, increase run off and reduces its infiltrations rates [25]. In addition the loss of nutrients alone resulting from soil erosion has an estimated cost to the united stated up to$20 Billion years. People were already aware of the negative consequences of soil erosion on agricultural production and the environment centuries ago [26]. As a result, indigenous soil and water conservation practices have existed for many years in some areas of Ethiopia [27, 28]. For instance, the United Nations Educational, Scientific and Cultural organization (UNESCO) has registered the terraces of the Konso people of Southern Ethiopia as one of the world heritage [26]. Soil conservation refers to the protection of fertile top soil from erosion by wind and water and the replacement of nutrient in the soil by means of cover crops, terracing, contour farming crop rotation etc. SWC can be defined as the combination of the appropriate land use and management practices that promotes the productive and sustainable use of erosion and other forms of land degradation. Generally, soil-water conservation includes all forms of human action to prevent and treat soil degradation [29]. As Tibabe and Mitiku, (2002) cited in [30], the aim of soil-water conservation is to facilitate optimum level of production from a given area of land while keeping soil loss below a critical value and protections of the life supporting capacity of soils such as soil quality, soil depth , soil structure, water holding capacity and soil productivity.

Successful Methods of Soil Conservations in Ethiopia: Soil conservation has become an integral part of land use and receives support within a social and economic environment which is conductive to the maintenance and improvement of soil capital [31]. The ultimate aim of soil conservation is to obtain the maximum sustained level of production for a given area of land whilst maintaining soil

Fig. 1(a-b): Typical (a) Stone and (b) Stabilized Soil Bunds at Dawuro Zone
Source: Kebede Wolka [39]

Fig. 2: Traditional Stone Bunds in Konso Area
Sourse: Kebede [39]

Fig. 3: Stone Bunds in Harerghe, Dire Dewa Watershed
Sourse: Kebede Wolka [39]

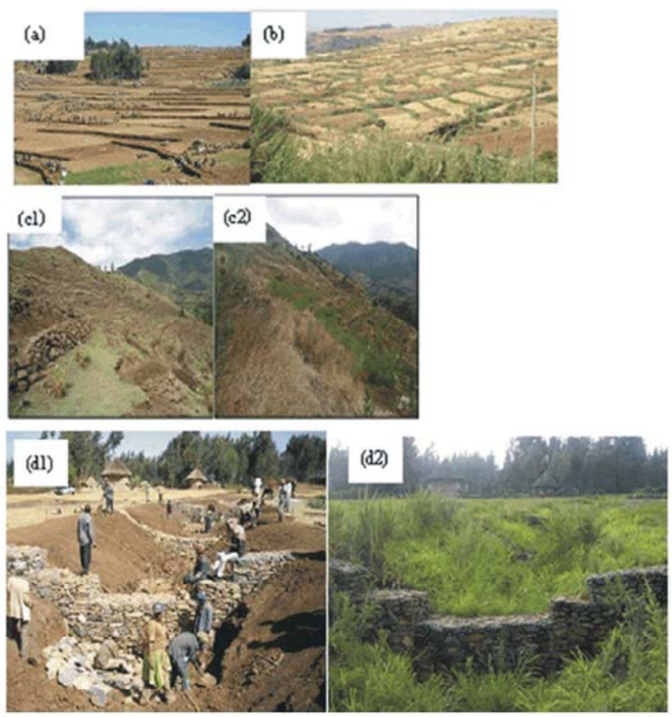

Fig. 4: Commonly implemented SWC measures in Ethiopia. (a) Soil bunds combined with trenches in crop lands, which are constructed by mobilizing the community through the free-labor day scheme; (b) soil bunds integrated with Sesbania trees in croplands, where the trees are also being used for animal feed through a cut-and-carry system; (c) exclosures combined with trenches in degraded steep slopes (c1 is before (2011) and c2 is after (2013) intervention), where the grasses/trees are harvested on a regular basis through a cut-and-carry system; and (d) check dams constructed across gullies (d1 is before (2012) and d2 is after (2013) intervention).
Source: Nigussie *et al.* [15]

loss below a threshold level which, theoretically, permits the natural rate of soil formation to keep pace with the rate of soil erosion [32]. There are two technical means for achieving these principles of soil and water conservation: the barrier approach and cover approach [33].

A conservation technique may be regarded as successful if it reduces the rate of soil loss to less than 20% of the rate without conservation and to less than 10 t ha^{-1} year-1 which is the commonly accepted as a "tolerable "rate of erosion [33]. Tenge *et al*. [34] reported that the grass strips, bench terraces and fanyajuu reduced soil loss by 40, 76 and 88%, respectively, compared to the land without those structures. Also, Herweg and Ludi [35] reported that in the Anjeni area of Ethiopia, graded soil bund reduced soil loss by 40% as compared with untreated plots. According to Tesfaye [36], the annual soil loss from croplands with level soil bunds reduced by 51% when compared to the control plot. In DebreMewi, Ethiopia [36]. Stone bunds and soil bund reduced soil loss by 72.9 and 83.7% respectively as compared to non-treated land [37]. The conservation techniques include both the new and traditional techniques such as traditional bunds and the newly introduced stone bund terracing, check dams, closures and plantations. It is a combination of all methods of management and land uses that safe guard the soil against deterioration by natural or man-induced factors [38].

Stone Bunds: These are barriers of stones placed at regular intervals along the contour. They have been used for generations in Ethiopia where they are locally known as "dhagaa" and in some parts of South Africa. The size of the stone bunds varies between 0.5-2m and may be 5 to 10m apart, depending on the availability of stones and the topography. Laying stone bunds in fields is a well-known technique to check runoff and to control erosion and is the most widely practiced technique by farmers [40]. Stone bunds retain or slow down run off and hence control erosion. They also allow the accumulation of soil, which may be redistributed after the bunds are dismantled [41].

In northern Ethiopia, especially in Tigray, Stone bund is 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. Another report in the Tigray region found stone bunds can trap 64% of the soil moved by water erosion. 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 tha^{-1} $year^{-1}$) [42] and required certain improvements/support measures to reduce absolute soil loss to are commended tolerable range [33, 43].

The SWC reduced soil loss by at least 61% in the Tigray region [44] and in Somali region [45] as compared with untreated sites. The effect of SWC structures is observed after some years of the structure being built. In three years old structures, Teshome *et al.* [37] observed 10 and 15% yield increments in DebreMewi and Anjeni (Ethiopia) watersheds, respectively, when compared to the yield before constructing those structures (fanyajuu, soil bunds). Regarding this, Wolka *et al*. [39] reported that 79.3% of the interviewed farmers perceived the increment of yield after 2 years of SWC structures (the soil bund and stone bunds) were put in place . Herweg and Ludi [35] reported that, a 4-50% decline in yield during the first 3-5 after the construction of SWCmeasures due to water logging problem; this was followed by subsequent yield increases ranging from 4-15% [35]; Nyssen *et al.* [27] found that after a few years of its construction, stone bunds increased cereal and *teff* yields by 8 and 11% respectively, even by considering the area lost due to the conservation structures.

Indigenous stone bunds (*kab*) have increased sorghum yield by 56-75% compared to other non-terraced land in north Showa, Ethiopia [46]. Kato *et al*. [47] showed that stone bunds, soil bunds and grass strips have robust and positive out puts on crops in the low rain fall areas of the Blue Nile basin in Ethiopia and high risk reducing effects in high rain fall areas. . This study indicated that grass strips have highest production elasticity among SWC technologies in their low rain fall areas. 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 [27].

Stone bunds contribute to agricultural productivity due to its moisture conserving role. Results of the analyses based on multiple plot observations per household indicated agricultural plots with stone bunds are more productive than those without it in dry areas but not in the high rain fall areas of northern Ethiopia [48].

Terracing: Yeshambel, reported that, in Konso Cultural Landscape is characterized by extensive dry stone terraces which witnesses hundreds of years of persistent human struggle to harness the hard, dry and rocky environment, which has resulted in the beautifully outlined rows of dry stone terrace. The terraces retain the

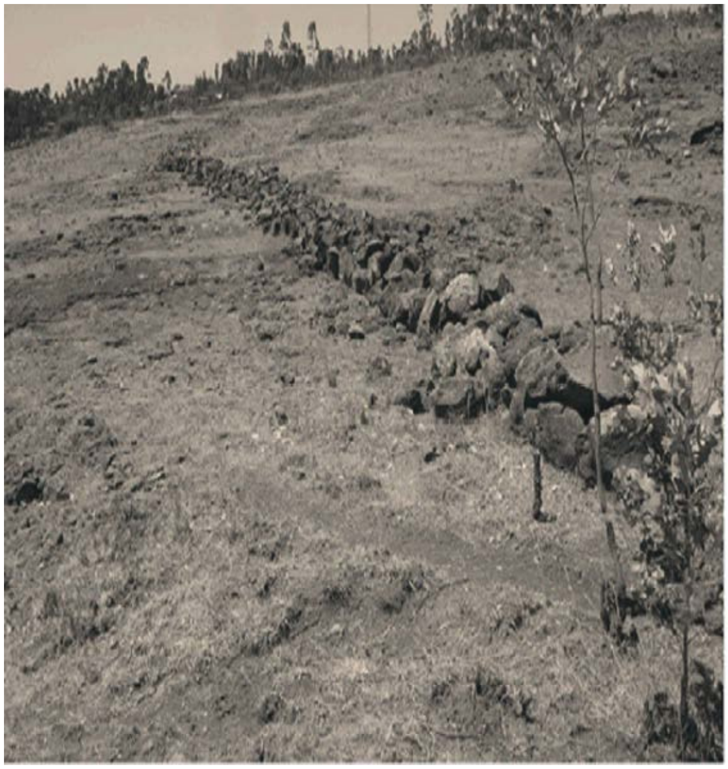

Fig. 5: Stone Bunds on Steep Slopes, Anshebeso (Siliti Woreda, SNNPRS, Ethiopia)
Source: Mushir and Kedru [49]

Fig. 6: Stone bund constructed in Afama Bancha Kebele (SNNPR, Ethiopia)
Source: Melese [40]

Fig. 7: Stone Terraces constructed by farmers in North Showa (Oromia)
Sourse: Habtamu [50]

soil from erosion, collect maximum water and discharge the excess and create terrace saddles that are used for agriculture. The terraces are the main features of the Konso landscape and the hills are contoured by the dry stone terraces that could reach at some places up to 5 meter high. The dry stone walled towns (Paleta) of the Konso are located on high hills selected for their strategic and defensive advantage. These towns are circled by, between one and six rounds of dry stone defensive walls, built using locally available rock [20]. Habtamu [50] reported that, Stone terraces were constructed in areas where construction material like stone is available. His study was focused on the conservation measure of soil and water practiced highly over farmland of Bole Becho and Iluna-egu-Kura village of the north Showa (Oromia Region, Ethiopia).

Soil Bunds: Soil bunds are constructed on agricultural and non-agricultural land with the aim of arresting soil erosion and improving the soil moisture profile [51]. The main aim of soil bund is by conserving the soil and harvesting the water, reduces and stops erosion and increases water holding capacity of the soil so as to enhance crop yield. Soil bunds also called fanyachini in Swahili is channel terrace structure constructed across the sloping arable land surface to intercept surface runoff. These structures break up a long slope into a series of short ones, each channel collecting the runoff from a definite area of the slope above it [52]. In the central highlands of Ethiopia, the soil bund reduced the yield of barley by 7% when the spaces occupied by the structures are taken into account and otherwise increased yield by 1.7% [42]. Possible biological measures such as enclosures, tree and shrub planting and management, agroforestry, strengthening the structures with grass or shrubs etc., should be given priority due to their multiple and sustaining roles. Many case studies indicated that biological measures and soil fertility management could improve effectiveness of the structures and soil fertility [42].

Agroforestry System: A system called "Agro forestry" has been widely promoted in the tropics in recent years. Here tree and field crops are grown together in the same field. The trees are often grown in narrow strips, often on the contour and are usually cut at different times so that they do not provide shade that would affect the field crops. The trees may be either fruit trees or trees, which have the ability to trap nitrogen from the atmosphere and return it to the soil where it can be used by other plants. A good ground cover of grasses, shrubs and/or leaf litter is needed if the trees are to effectively control water erosion. Agro-forestry is also one of the practices mainly at the low land areas in the Woreda where Mango (*Mangifera indica* L.) is well integrated with the cultivated crops and considered as an important component of the farm. The best example is *Moringa stenopetala* (locally also called to be Moringa) which has several purposes; used for shade, main diet, medicine. Other tree species in Konso are: *Juniperus procera,*

Fig. 8: Soil Bunds in Danech (Siliti Woreda, SNNPRS)
Source: Mushir and Kedru [49]

Fig. 9: Agro-forestry practice (DiggaWoreda, Oromia)
Source: Tolera [54]

Fig. 10: Vetiver Hedgerows on Maize Farm before& after Harvest (Metu, Oromia)
Source: Tekalign [56]

Euphorbia spp. Terminalia browenii, Olea africana, Ficussori, Cordia africana, Sterculia africana, Accia abysinica. Among these, *Juniperus procera* has a high significance in Konso's rituals. Thus, it seems that in addition to trees role for indigenous soil conservation practices in agro forestry form has strong attachment the society cultural practices [20].

Agro forestry is also a valuable traditional practice which plays an important role in maintaining ecological stability. Trees used in agro-forestry system can also provide a variety of services such as being a form of saving and investment, protection from wind, employment opportunity, increased amount of water for plant growth, improved seasonal availability of water, protection of soil from erosion and loss of nutrients, restoration of degraded soils and improvement of soil moisture and fertility, maintenance or increase in species and habitat diversity and improved conditions for natural regeneration of most desirable species [53].

Grass Strip: Grass strip is the biological land management practice in Ethiopia which is being practiced by farmers in their fields by planting vetivar and native grasses along the contour at the top and in between the farmland. Besides serving as fodder for the cattle, also impacts soil. The barriers were usually of grasses, which has been planted or left to grow naturally in narrow strips along the contour at intervals across the slope of a field. When planted as a contour hedge it acts as a continuous filtering system that slow down run off and collects soil sediments at the hedge faces [54]. Since Vetiver grass root system grows more vertically than horizontally, it does not compete for more space with crops planted in the field. Alemu Mekonnen indicated that the grass can be effectively used on the existing soil bunds, contours without any physical structure, waterways and cutoff drains, around ponds reservoirs, irrigation and drainage canals, micro basin and check dams [11]. The vetiver system reduces soil loss from farm land by 90% and reduces rainfall runoff by 70% [55]. In addition, the leaf of vetiver grass is used for fodder, roof thatching, making ropes, mats, hats, baskets, mattress stuffing, making brooms and others. It is used also as insect and rodent repellents [56].

Leaving Crop Residues and Mulching: Residue management is an act of leaving crop residue on the field after harvest mainly for the purpose of animal feed, fuel and construction materials. Despite its uses as animal feed, fuel and construction purpose crop residues are very important for crop land improvements by enhancing water availability to crops and increasing the soils water retention capacity [57]. Until the recent years returning crop residues to soil were not common practices for most farmers, who prefer to use for livestock feed, fuel and construction materials or to burn or remove from the fields [54]. This finding was found to be in agreement with the works [9], reported that, mulches are materials placed on the soil surface to protect it against raindrop impact and erosion and to enhance its fertility.

Another methods of soil conservation is Mulching which the covering of the soil with crop residues such as straw, maize or sorghum stalks or standing stubble. The cover protects the soil from raindrop impact and reduces the velocity of runoff. Maintaining crop residues or mulches on the farm controls effectively soil erosion and has considerable potential for the restoration and maintenance of soil fertility. Mulching is one of the most effective methods to minimize erosion. A crop residue covering the ground intercept raindrop impact, preventing splash erosion, slow down the water flows and increases the infiltration rate. It also encourages insects and worms to take holes into the ground, thus increasing the permeability of the soil [1]. Most farmers in Konsoworeda are using surface mulches on their fields, thus providing a protective cover at a time when crop cover is not present. Some farmers left crop residue while others used by branches. The benefit of protective covering was widely appreciated, as was the improved infiltration rate afforded by the techniques and reduced evaporation rate. Further stated objective is the addition of nutrients to the soil through the decomposition of the organic matter. However, the density of mulch viewed in many fields was below the level required to be most effective as protective cover since the use of residence as animal food was witnessed in many households of the area [20].

Crop Rotation: Crop rotation is a practice of growing different crops one after another on the same piece of land, season after season or year after year. It is a valuable traditional practice, which plays an important role in maintaining ecological stability and improving agricultural productivity. If the same crop is grown on a piece of land year after year, the soil nutrient depletes sharply and as a result yield decreases. Nevertheless, if different crops are rotated, the depletion of soil nutrient and the decline in crop yields is minimized [54]. The use of crop rotation is widespread phenomena in the Konsoworeda where maize, ground nut and sorghum grown rotationally. Crop rotation is used by the farmers important for different reasons including soil fertility, thereby improved crop yield. The farmers of the area know that as of the scientific method improved soil fertility can be achieved by alternating high residue producing crops with the growing low residue producing crops [20].

Crop differs in their effect on soil. Some crops restore or build fertility of the soil, while others deplete its fertility. For instance, legumes fix atmospheric nitrogen and hence enrich soil fertility. Forage legumes and grasses provide good ground cover that protects soil erosion and enriches the soil with organic matter, which in turn improves the structure and biological activities. Cereals such as sorghum and maize deplete soil fertility. Crop rotation, in addition to fertility restoration and soil and water conservation use, is a traditional cropping practice for controlling diseases, pest and weed infestation. Different crops are not equally susceptible to pests or diseases. Growing the same crop every year leads to build up of pests and diseases in the field, which attack that particular crop [54].

Crop rotation maintains or improves productivity as a result of improved fertility of the land and reduced pest/diseases problems. Different crops vary in their response to different pests and diseases. Some crop are resistant to some pest and disease including weeds, while others are susceptible. Sorghum is more susceptible to the parasitic weed (*striga*) than leguminous crop (e.g. chickpea)and oil crop (*Noug*). Therefore, it is advisable to grow legumes or oil crops after sorghum than growing sorghum after sorghum or millet after sorghum and vice-versa, MoFED [1]. For Teklu and Gezahegn, the major cereals, after legumes or oil crops are rotated mainly for soil fertility maintenance, weed and disease control [58].

CONCLUSION

Soil is one of fundamental natural resources to support life on earth. It is finite and non-renewable natural resource which takes between 200 and 1000 years for 2.5 cm of topsoil formation under cropland condition. Degradation due to soil erosion and nutrient depletion are the most challenging environmental problems in Ethiopia. The Ethiopian highlands have been experiencing declining soil fertility and severe soil erosion due to intensive farming on steep and fragile land. The population in the rural areas is increasing and more food is required to feed this population. On the other hand the land size used by farmers is reducing. These situations forced the farmers to use the land intensively throughout the year that has resulted in soil degradation. In Ethiopia, water erosion is the most important land degradation process that affects the physical and chemical properties of soil resulting in on-site nutrient loss and off-site soil sedimentation.

Soil conservation has become an integral part of land use and receives support within a social and economic environment which is conductive to the maintenance and improvement of soil capital. The ultimate aim of soil conservation is to obtain the maximum sustained level of production for a given area of land whilst maintaining soil loss below a threshold level which, theoretically, permits the natural rate of soil formation to keep pace with the rate of soil erosion. It is clear that soils with low fertility are unable to allow sufficient crop cover to sustain life. Erosion and low humus content of such soil decrease infiltration and moisture holding capacity of the soil. These all quest for the importance of soil conservation measures. Thus, it is increasingly recognized that adequate conservation of soil resources is a precondition for sustainable rural development strategies particularly in the highlands of Ethiopia. Generally, Practicing indigenous and introduced soil and water conservation practices such as soil bunds, stone bunds, agroforestry, vetiver grass, crop rotation, mulching/residue management, hillside terraces and grass strip or hedgerows etc. to either divert runoff into safe channels, such as grassed water ways, or reduce it by promoting infiltration is the ultimate aim of soil conservation to obtain the maximum sustained level of production for a given area of land whilst maintaining soil loss below a threshold level which, theoretically, permits the natural rate of soil formation to keep pace with the rate of soil erosion.

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