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Review Article
Soil and Water Conservation Practices on Crop Productivity and its Economic Implications in Ethiopia: A Review

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Abstract
Soil erosion is a serious problem in Ethiopia. Appraisal on soil and water conservation and its implication on food security are crucial. The aim of this study was to assess farmers' perception on soil and water conservation practices on crop productivity and its economic implications and identify major constraints on soil and water conservation in Ethiopia. Physical and biological soil and water conservation practices are important to improve crop yield by enhancing soil moisture, conserving rainwater and controlling erosion occurred in the area. However, implementation of soil and water conservation is not an easy process, due to complex, mountainous, fragile ecosystem with inappropriate land management practices and intensive rainfall and steep slope resulting in big gullies, severe soil erosion and poor soil fertility. In Ethiopia, there are many soil and water conservation practices that are important to reduce the damaging effects in associated with erosion and water loss but, in most cases, farmers neglected from decision making during the selection, planning and implementation processes of soil and water conservation measures and most activities were undertaken without their interest. Determinants of farmers' perception to invest in soil and water conservation practices are determined by the socio-economic, institutional, attitudinal and biophysical factors. Based on the overall consideration, lack of integrated bio-physical measures, absence of integrating indigenous practices, lack of considering socio-economic profile, low perception and participation of farmers, poor conservation design, improper land use, less maintenance, weak monitoring and evaluation of soil and water conservation practices are the major constraints that determine the implementation of soil and water conservation in Ethiopia.

Key words: Constraints, decision making, effectiveness, land degradation, soil erosion

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INTRODUCTION

Land degradation, in the form of soil erosion and nutrient depletion is a major threatening factor for aggravating food insecurity and exacerbate sustain ability of agricultural production in Ethiopia[1]. During 1981 and 2008, the total land degraded in the country is estimated to be 297,000 km^2. Annually, the mean rates of soil loss associated with croplands have been about 42 t ha^{-1}[2,3]. Poor water shed management, population growth and inappropriate farming practices have contributed for a lion share of the losses caused. Besides, poverty with rapid increase in human population combines with land degradation poses a serious threat to the national economy and household food security[4]. Furthermore, soil erosion hampers agricultural productivity through deteriorating soil quality (loss of organic matter and mineral contents) by means of excessive surface runoff[5-7]. As far as surface runoff is concerned, the trans-boundary rivers that originated from Ethiopian highlands and carries about 1.3 billion tyr^{-1} of sediments to neighboring countries[8]. In addition, soil erosion also causes the change in physical properties of the soil such as texture, infiltration rate, bulk density, water holding capacity and root depth. However, in Ethiopia for the past decades, an attempt was made to undertake mitigation measures on soil erosion problems using different approaches for the sustain ability of crop production[9,10]. Besides, watershed management approach has been applied in the country to reduce environmental degradation and to enhance agricultural productivity which supports sustainable livelihoods security of the households. In this regard, the use of soil and water conservation practices in association with crop production is determined by the combined effect of biophysical and socio-economic factors[9].

Improved production and productivity of crop yield is the major target of livelihood security strategies. Crop production, soil and water conservation objectives are highly harmonizing, since conservation of water, soil and vegetation leads to higher productivity of crops and livestock farming[11,12]. In this regards, there are some efforts exerted so far in relation to watershed management and soil conservation measures during the 1970 and 1980s through local communities, mainly for food for work programs. The approach was criticized for its top-down approach in many part of the country. Currently, the government of Ethiopia has also been undertaking soil and water conservation through integrated and participatory watershed development approaches to improve rural livelihoods through sustainable natural resource management to ensure sustainable development for present and future generations. Accordingly, this review was designed to focus on the impact of soil and water conservation practices on crop production and productivity, how agricultural crops influenced by soil and water conservation structures and identify major constraints on soil and water conservation practices in Ethiopia[13,10].

Impact and problem of soil and water conservation on crops: Soil erosion is one of the main problems in developing countries in general and in Ethiopia in particular. The complex, mountainous and fragile ecosystem with inappropriate land management practices and intensive rainfall and steep slope soil erosion resulting in big gully formation and lead to soil erosion and poor soil fertility[14,15]. As an approach, physical soil and water conservation measures are important to improve soil fertility, crop yield increment particularly in highly degraded areas[16]. In most physical soil and water conservation structures are improve crop yield by enhancing soil moisture and controlling erosion occurred in the area[17]. These structures are increasing the efficiency of commercial fertilizer on crop response as well. Soil and water conservation (SWC) structures raise the retention of moisture and soil particles, together with fertilizer, within cropland which might otherwise be washed away by water erosion. In the absence of physical soil and water conservation structures and ecological agriculture the entire cropland area might be seriously eroded and degraded and crop yield would be expected to decline[18]. Even though, physical soil and water conservation structures are improve crop production, it also reduce the area available for cultivation and crop production by occupying a larger proportion of cropland[18,15].

In many cases, population growth directly depends on cultivable land, the total decrease of cropping land as a result of SWC structures would become challenging. Reports indicate that, depending on slope and structure type, significantly high proportions of cultivable land are occupied by structures[19]. Depending on slope (for a slope category from 5 to >55%) and soil stability, grass strips, bench terraces and fanya juu occupy 1-15%, 5-42% and 8-40% of cultivable land areas, respectively[19]. 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%[20]. Vancampenhout *et al.*[21] estimated that stone bunds occupy about 8% of the farmland in Northern part of Ethiopia. In experimental plots established in the central highlands of Ethiopia, soil bunds occupy 8.6% of cultivable land[22]. In Southern region of Ethiopia, local farmers grew a number of crops without conservation structure and obtained very low yield even with application of commercial fertilizers[23]. However, after construction of conservation structures, agricultural crops yield were significantly increasing, the amount differs from farmer to farmer as the style of the management of the soil also by different from farmer to farmer. For instance, yield of *teff* (*Eragrostis abyssinica*) was increased from 320-560 kg ha^{-1} and from 300-800 kg ha^{-1} on different farms in the area[23]. Likewise, the haricot bean yield increased from1800-3200 kg ha^{-1}, from 2240-3680 kg ha^{-1} and from <2000-4000 kg ha^{-1} on different farms. Again, yield of wheat was increased from 2400-3200 kg ha^{-1} and from 2000-8000 kg ha^{-1}. Maize yield was increased four folds, from 4000-16000 kg ha^{-1}. Potato also followed similar trend, it was increased from <4000-16000 kg ha^{-1}. Sweet potato, which is the major food crop of the area showed 750% yield increment i.e., from 2400-18000 kg ha^{-1} in Southern part of the country[23].

In the same manner, constructing bunch terrace increased crop yield but the yield is vary with the degree of land degradation before terraces are built[24]. Therefore, the prevention of runoff through physical conservation structures led to noticeable increases in agricultural crop yield in the highland part of the Ethiopia. Yet, all agricultural crops did not show similar tendency as yield increment after conservation structure implemented in the area. For example, maize showed highest yield increment due to its sensitivity to moisture stress. On the other hand, *Sorghum* is relatively tolerant to drought and did not show the same response as maize crop[24]. In addition, the positive correlation between yield and silt content in plots with wheat probably reflects the influence of silt on the moisture holding characteristics of the otherwise sandy soils. The availability of phosphorus seems to explain parts of the variability in yields between the soil groups. However, mainly a group effect since the available phosphorus contents and yield are higher on the terrace benches[25].

Impact of soil and water conservation structures on crops: In agricultural system, the objective of improving the productivity, profitability and prosperity of the farmers and achieving agricultural development on an ecologically sustainable basis can be attained only when conservation, development and management of the land and water resources are assured[26]. The more of the soil is covered with vegetation, the better is soil protection against erosion (canopy cover reduces soil erosion by intercepting the rainfall and reducing both the kinetic energy of the raindrops and splash detachment). Conserving soil and water and maintaining long-term soil productivity depend largely on the management of cropping systems, which influence the magnitude of soil erosion and soil organic matter dynamic[26]. Thus, different researchers implemented various researches on soil and water conservation measures to evaluate the effect of agronomic practices on crop production in different part of Ethiopia. Reducing tillage and maintenance of ground cover with crop residues may increase crop production and water availability in semi-arid areas[27]. Therefore, conventional, tied ridging and zero-tillage were compared with 0, 3 and 6 mg ha^{-1} of *teff* straw applied after tillage. The interaction of tillage and straw application rate has a significant difference on crop production, 70 and 46% increases in yield with 3 mg ha^{-1} of straw applied for conventional and zero tillage, respectively. Nevertheless, in some places the impact of tied-ridging on crop yield is negligible. Growing *teff* in association with nitrogen fixing trees like shrub species in alley cropping agro forestry system had sustained crop production in Ethiopia[28]. Most of the time, mulching and application of pruning of *Sesbania sesban* and *Croton macrostaychus* green leaf biomass to the *teff* cropped field increase production and straw yield[28]. The authors conclude in the report, incorporation *Sesbania sesban* increases from 91-115% grain and 63-113% straw and *Croton macrostaychus* increases from 34-50% grain and 14-49% straw yield over *Cajuns* and *Acacia* species, respectively.

Effect of biological soil and water conservation measures on crops: Biological soil and water conservation measures are very important for erosion control and crop yield increment. On contrary, biological conservation measures did not contribute a significant role on crop yield and interest of household income in general, nevertheless most studies revealed that, biological conservation measures are having significant role in crop production[18]. In a nut shell, it is to be noted that there were positive trends which all together should guide soil and water conservation policy makers to identify important factors influencing the contribution of such a program and reconsider the design and implementation of the interventions.

Off-site cost of erosion: Incentive for investment in land protection related activities in developing countries arising from soil erosion and other institutional problems which would be resulted in market failures[29-31]. Market failure happens when the price mechanism fails to allocate scarce resources efficiently or when the operation of market forces lead to a net social welfare loss. An economic outcome is said to be Pareto optimal if it is impossible to make some individuals better off without making some other individuals worse off. This concept offers a minimal test that any social optimal economic outcome should pass[32]. It is defined in contrast to a theoretical ideally-operating economy. When individuals are free to trade in a competitive market place where there exist no externalities in production or consumption, the resulting distribution of resources in the economy is Pareto-efficient: no person can be made better off without making some other person worse off. At this equilibrium, the price system has coordinated the activities of all market participants such that all resources have moved to their most highly valued uses. Work by Kenneth Arrow, Gerald Debreu and Francis Bator in the 1950s provided formal proof of the conditions under which the market equilibrium is Pareto-efficient: The first fundamental theorem of welfare economics. The first welfare theorem refers only to the efficiency of the equilibrium, it says nothing about whether the resulting allocations are fair or just. However, many potential allocations satisfy Pareto-efficiency. The second welfare theorem shows that any efficient equilibrium can be reached through the operation of competitive markets with redistribution of individual endowments or wealth. Consequently, if the results of a market process are deemed to be inequitable, economists would argue that any correction should be implemented via changes in endowments rather than through interventions in the workings of the price system.

The implication of this on soil resource management in developing countries like Ethiopia is that individual farmers lack incentives to take into account the off-farm costs or benefits generated from their farm practices during land use decisions. The presence of market failure results in insufficient incentives for individual farmers to practice soil conserving agricultural practices and encourages further soil erosion and land degradation. This leads to non-optimal resource allocation and utilization and necessitates government intervention to ensure the efficiency of resource allocation. Market failures in these countries occur due to the presence of off-site costs arising from soil erosion, lack of information, risk and uncertainty, poor specification of property rights, poorly developed or non-existent credit and insurance markets, as well as other institutional factors[33]. The economic rationale for public investment in soil and water conservation is that it improves resource allocation efficiency in the absence of market incentives for erosion control. On the other hand, according to the report of International Livestock Research Institute (ILRI) several different types of direct economic incentives have been used to develop the ability and willingness of farmers to use soil and water conservation practices. The most widely used direct economic incentives have been compensation for labour and support with equipment[34]. Farmers evaluate multiple effects of the problem in their SWC investment decisions. The primary objectives of farmers in relation to SWC investments are ecological restoration (erosion control, enhanced soil fertility and increased water retention), economic benefits (increase production and decrease costs) and diminishing socially adverse effects of erosion and SWC measures (Table 1). In addition to this, improving the livelihood of the farmers through comprehensive and integrated natural resource management and development is another objective[35]. The research result of this study is presented in the following Table, farmers and experts gave weightings for the different evaluation criteria (Table 1). The results show that farmers and experts gave different weights and that these vary by slope category. The ecological impact criteria had the highest weighting within the steep slope category. On the other hand, economic impact criteria received the highest weighting in the gentle slope category. According to the farmers' views steeper slopes are more prone to erosion and that it is relatively more important to preserve them. The gentle plots on the other hand, have higher economic potential.

Decision making process: According to researchers conducted by different scholars, farmers were totally ignored

Table 1: Farmers/experts evaluation criteria for SWC

Objectives	Criteria	Unit of measurement
Ecological impacts		
Erosion control	Minimal soil loss	Rank
Enhance soil fertility	Minimal nutrient loss	Rank
Water retention	Maximize water retention	Rank
Economic impacts		
Crop yield	Maximize crop yield	Rank
Grass production	Maximize grass production	Rank
Labor requirements for establishment	Minimize labor for establishment	Rank
Maintenance costs	Minimize maintenance cost	Rank
Social and other impacts		
Ox-plowing convenience	Maximize ox-plowing convenience	Rank
Risk of pest harboring	Minimize risk of pest harboring	Rank
Avoid dispute with adjacent farmers	Minimize dispute with adjacent farmers	Rank

Table 2: Farmers reasons for discommending externally introduced SWC measures (fanya juu)

Farmers' reason	Doreba (%)	Hobichika (%)
Takes up too much land	17.3	19.2
Does not protect from soil erosion	22.4	30.9
Worsens the problem of soil erosion	46.3	43.6
Breeds pests like rats and other	7.6	4.2
Other*	6.4	2.1

*The category 'other' includes% of respondents who gave answers different from the enlisted ones

Table 3: Farmers adoption decision towards soil conservation measures

	Farmers' response	
Adoption judgment of SWC	Frequency	Percent (%)
Very good	39	37.5
Good	45	43.3
Poor	20	19.2
Total	104	100

from decision making during the selection, planning and implementation processes of SWC measures and the activities were undertaken without their interest. Farmers were considered ignorant of SWC technologies and have been given little attention in decisions making processes related to SWC technologies[35].

Effective protection and conservation of SWC can be realized only when farmers accept and decide on the benefits of SWC technologies and actively involved in the implementation and maintenance processes as recommended by those researchers. Farmers were at times right in rejecting of the introduction SWC technologies because it would cause greater damages than would happen without the measures[36]. The reasons given by household farmers for discommending fanyajuu construction in their cultivated lands as illustrated in Table 2. Of those farmers who responded that they were participating in the conservation activities against their interest, the majority reason given was that the fanyajuu bunds rather heighten the severity of the problem of soil erosion (55 and 60% of the total in both study sites). According to this research, fanyajuu bunds constructed in the previous years had shown the farmers that the structures definitely cause more erosion damage in their fields[36]. The farmers brought up failure of the bunds as the structure collects too much water all along its length, the farmers reported, it spills down slope at its weakest point and then releases the stored energy-the water. Once this happens to a bund, it becomes a cause of the disintegration of several bunds down slope. The cumulative damage by this chain process becomes massive. In addition, being its space taking and providing fertile ground for pests to reproduce were also mentioned as important problems of the fanyajuu structures (7.6 and 4.2% of respondents). Moreover, the farmers added that the fanyajuu structure caused moisture stress to their crops by draining the water off the fields with little time given for infiltration to take place[37].

About 81% of the farmers either partially removed or modified and maintained the soil and water conservation measures as indicated in Table 3. Moreover, among the remaining farmers (19%) of the respondents totally removed the soil conservation structures. These findings reconfirm other studies that argue farmers in developing countries often reject externally introduced SWC technologies because of the inappropriateness to farmers' requirements and local farming systems[38-40]. The practice has largely remained delivery oriented in which the farmers are forced to implement conservation measures designed for them by technical experts[41].

The majority of the farmers have been reported to have totally or partially removed conservation structures constructed on their plots[42]. This was due to the farmers' lack of knowledge and skill to adapt land management technologies and absence of intervention measures by government and nongovernmental organizations. Investigations made in other study areas also came up with similar result. According to Habtamu revealed that 53% of farmers interviewed removed introduced conservation[43].

Determinants and constraints of farmers' perception to invest in soil and water conservation: As participation constraints credit, land use security and extension services could be an effective means to increase the share of farmers implementing soil conservation measures. However, trust in contract terms and conditions appear to play an important role. Farmers living in the most erosion prone areas are most likely to participate, while farmers taking soil conservation measures already are less likely to enter into a contractual agreement with the local government. Farmers are not taking soil conservation measures seriously unless the contract price is lower than or equal to the income losses suffered from soil erosion[41]. The most important factor discouraging farmers from participating in soil and water conservation practices freely was the perceived ineffectiveness of the structures under construction. Awareness about soil erosion as a problem, labor shortage and land tenure insecurity were found to be less important in providing an explanation for the disinterest shown by most of the farmers[5,39]. According to the research finding large household sizes, adequate labour, old age, high degree of contact with development agents (DAs), willingness to adopt new SWC technologies and their income source have been the major influencing factors for participating in SWC activities[44]. In Ethiopia, farmers'

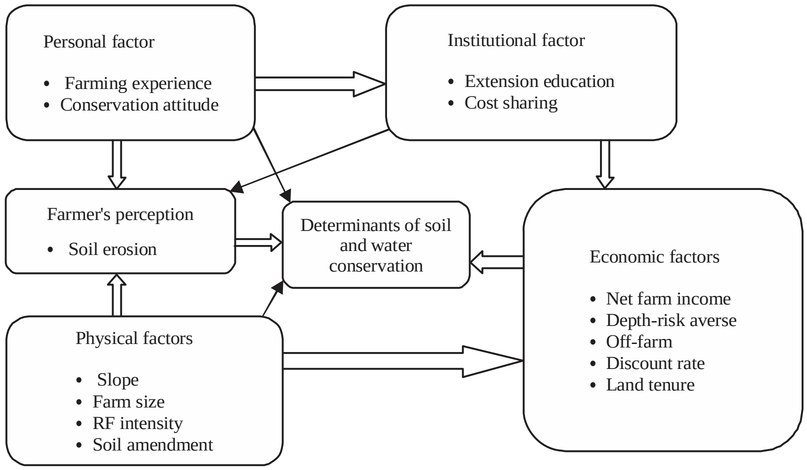

Fig. 1: Determinants of SWC practices

Table 4: Farmers' average scores of different SWC practices based on evaluation criteria

	Alternative			
Technical criteria	SB	SB+Vg	SB+Eg	SB+Ss
Reduce soil loss	3	4	5	4
Reduce nutrient loss	2.5	4.5	5	4.5
Improve soil fertility	2.5	4.5	3.5	4.5
Retain soil moisture	2.5	4.5	4.5	4.5
Average	2.63	4.13	4.5	4.38
Economic criteria				
Increased crop yield	2	3.5	4	4.5
Increased fodder	1	3	5	4
Maximize cultivable area	2	2.5	3	3
Low labor requirement	3	3	2.5	3
Average	2	3	3.63	3.63
Stability criteria				
Easily established	2.5	3.5	4	3.5
Easily for maintenance	3.5	3	4	3
Suitable for free grazing	3	3	1.5	1.5
Average	3	3.17	3.17	2.67
Overall average score	2.5	3.45	3.82	3.64

5: Best, 4: Very good, 3: Good, 2: Average, 1: Not good, SB: Soil bund alone, SB+Vg: Soil bund with Vetiver grass, SB+Eg: Soil bund with Elephant grass, SB+Ss: Soil bund with *Sesbania sesban*

willingness to use soil and water conservation practices is largely determined by their knowledge of the problem of soil erosion[45]. The determinants of farmers' perception to invest in soil and water conservation practices were highly determined by socio-economic, institutional, attitudinal and biophysical factors. Thus, a better understanding of constrains that influence farmers' perception is very important while designing and implementing SWC technologies[46]. Lack of integrated bio-physical measures, absence of integrating indigenous practices, negative impacts of incentives, lack of considering socio-economic profile, low perception and participation of farmers, poor conservation design, improper land use, less maintenance, weak monitoring and evaluation of soil and water conservation are the major constraints exist[47]. The adoption and use of soil and water conservation practices was conceptualized as the discussion determinants of soil and water conservation measure[48]. Each category of factors hypothesized to influence one or more of the decision making process components as presented in the Fig. 1. Each component can be visualized as a major step in the decision to control soil erosion.

Effectiveness: Effective SWC management activities are very crucial for achieving and sustaining food security in farm households. As the research report by Adimassu *et al.*[49], the values reflected the perceived degree of importance of each SWC practices based on their criteria below in Table 4. According to him, farmers gave higher scores for criteria related to technical effectiveness for most SWC alternatives (SB+Vg, SB+EG and SB+Ss). This implies that these SWC practices are more technically effective than economically efficient. The overall average shows that farmers gave the highest total score for SB+Eg followed by SB+Ss and SB+Vg. In all criteria, farmers gave the lowest total score for soil bund alone (SB). This is because, in SB alone there is no grass or shrub to improve its technical effectiveness and financial efficiency. A study in the central highlands of Ethiopia shows that SB alone reduced crop yield by about 7%, which is entirely explained by the reduction of the cultivable area by 8.6%[50]. Similar results were reported in the highland areas in Ethiopia that soil and stone bunds decreased crop yield for the 1st 5 years[21,51]. This implies that suitable measures are needed to compensate the yield losses caused by the construction of soil bunds. So, it is crucial to plant grasses and shrubs on soil bunds to re enforce the structures and increase the financial efficiency of the soil bunds.

CONCLUSION

Soil erosion is a cause of soil fertility loss, reduce crop yield and thereby exacerbates the risk of food security. Physical and biological soil and water conservation structures are common in Ethiopia, however, its implementation of the structures are difficult, due to lack of integration bio-physical measures, absence of integrating indigenous practices, negative impacts of incentives, lack of considering socio-economic profile, low perception and participation of farmers, poor conservation design, improper land use, less maintenance, weak monitoring and evaluation of soil and water conservation are the major constraints that determine the implementation of SWC in Ethiopia. Besides, the system totally neglect farmers' decision making during the selection, planning and implementation processes of SWC measures and most activities were undertaken without their interest. Therefore, SWC strategies must be linked with farmers' indigenous knowledge, willingness and decisions before implementation of SWC practices.

SIGNIFICANCE STATEMENTS

Poor watershed management, rapid population growth and inappropriate use of farming practices have contributed for a lion share of the losses caused and pose a serious threat to the livelihood security and which is yet to be studied before. Cognizant of these facts, this study had high contribution for researchers who working on soil and water conservation and policy makers for development of different soil and water conservation practices in the country.

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