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Construction of Soil Conservation Structures for improvement of crops and soil productivity in the Southern Ethiopia

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Abstract

Soil erosion is one of the major agricultural problems in the highlands of Ethiopia. Deforestation, overgrazing, and cultivation of slopes not suited to agriculture together with the farming practice that do not include conservation measures are the major causes for soil erosion in much of Ethiopia's highland areas. Degraded soils are also the major constraints to agricultural production and food security in the Southern Ethiopian highlands. A study was conducted on watershed that covers 544 ha at Gununo area of Wolaita Zone in the Southern Ethiopia with the objective of conserving soils by constructing soil conservation measures. The soil conservation measures were implemented fully with the participation of farmers. A survey was conducted and soil erosion and fertility decline were identified as top priority problems of the watershed. Then discussion was made among PAs leaders, researchers, and the community about the solution and soil conservation measures were constructed and bund stabilizers (Elephant grasses) were planted by collective action. Continuous participatory monitoring and evaluation was made for maintenance of the structure, improvement of soil fertility, and observation of its effect on crop yields. Soil and crop data were collected after implementation of conservation measures and compared with the baseline information. A total of 9965 m soil conservation structures were constructed, out of which 66.9% and 30.5% are Fanya-juu and soil bund, respectively. The soil conservation measures adapted well to the local conditions and protected the soil from being eroded. The colour of the soil was changed to black and organic matter content was increased. Yield was increased by 22 % on some farms and 15 fold on other farms within one year of bund/fanya-juu construction and by >50 % after 3 years with similar farming practices. The land that could not grow any crop yielded 800 kg/ha of haricot bean after implementation of soil conservation measure. The purchasing power of the farmers increased after they conserved their soil. In conclusion, construction of soil conservation measures in the degraded highlands and stabilizing with multipurpose plant species is very important to conserve the soil and increase crops yields.

Key words: Soil conservation measures, Degraded soils, Soil erosion

Introduction

Highland areas are characterized by high population, high rainfall and sloppy lands. Degraded soil is the principal environmental factor behind declining per capita production in Sub-Saharan Africa being caused by nutrient mining, soil erosion, poor land management and lack of resources. How to maintain fertility of productive soil and rehabilitate degraded arable lands that are on the verge of going out of production are the major concern of many stakeholders in highland areas (Tilahun Amede, 2003). Degradation of arable lands became the major constraint of production in East African highlands, due mainly to nutrient loss resulting from soil erosion, lack of soil fertility restoring resources, and unbalanced nutrient mining (Amede *et al*., 2001). In Ethiopia an estimate 17% of the potential annul agricultural GDP of the Country is lost because of physical and biological soil degradation (Tilahun Amede *et al.*, 2007). Causes for land degradation are: human population growth, poor soil management, deforestation, insecurity in land tenure, variation of climatic conditions, and intrinsic characteristics of fragile soils in diverse agroecological zones (Bationo *et al*., 2006). Soil erosion is one of the major agricultural problems in the highlands of Ethiopia. The Ethiopian highlands occupy 44% of the total area of the country, 95% of the land under crops and 90 % of the total population and 75% of livestock (Amede *et al.*, 2001). Degraded soils are the major constraints to agricultural production and food security in the Southern Ethiopian highlands (Tilahun Amede *et al*., 2006). Deforestation, overgrazing, and cultivation of

slopes not suited to agriculture together with the farming practice that do not include conservation measures are the major causes for soil erosion in much of Ethiopia's highland areas. Population pressure and soil erosion in the areas are important causes for declining of arable lands. The productivity of arable lands in the highlands is decreasing due to the washing away of the fertile top soil by water erosion. The increasing population and pressure of over cultivation and over grazing accelerated soil erosion. Heavy tropical precipitation falling on areas of thin vegetation is causing a marked increase in soil erosion In addition to the fertile top soil, erosion washes seeds sawn and applied fertilizers. Soil fertility is declining most rapidly and resulted in low crop yields and livestock numbers that led to reduced food security and increased poverty in the highlands of Southern Ethiopia. According to Pound and Ejigu Jonfa (2005), causes of soil fertility decline in the area are clearing of forests, removal of crop residues from the fields, land fragmentation, overgrazing, low fertilizer inputs, inadequate soil conservation, cropping of marginal lands, poor soil management, increased pressure on land due to increased population and reduced in livestock numbers (and therefore manure).

Gununo, which is located about 430 km from Addis Ababa in the Southern part of Ethiopia, is one of such highlands which are experiencing the aforementioned problems. It is characterized by very high population density (about 450 persons per kilometre), which resulted in a very small land holding averaging about 0.24 ha per household (Amede *et al.,* 2001). The population density indicates that pressure on the natural resources of the area is growing rapidly. The soil of Gununo is very highly degraded, mostly because of soil erosion, and crop production is very difficult. Amede *et al. (*2001) witnessed that aalthough the soil is deficient in nitrogen
and phosphorus, high level application of inorganic N and P did not improve maize yield as the land was highly degraded and the organic matter was totally depleted (Table 1).

On some farms nothing could be harvested although the crops were planted with application of good amount of fertilizers as both the fertilizers and the seeds were washed away by soil erosion. On some fields nothing could be grown even no weeds. One farmer (Mr. Admasu) said that he left his farm without cropping for three years but no change was happened. Those farmers who struggled to conserve their soil using some traditional soil conservation measures like diverting the water way and making a small soil bund using oxen could obtain 20 kg yield after sowing 10 kg of seeds. However, on some parts of the farms and in some years nothing could be grown. One farmer (Mr. Temesgen Welebo) said that he became pessimist and worried how to feed his family and finally decided to leave the area for finding job because his farm was rock outcropped. Soil fertility improvement on sloppy lands without soil conservation is unlikely as both mineral fertilizers and organic matter applied can be lost with erosion. A soil with N and P contents of 0.2 % and 7 ppm, respectively, remained with the same nutrient contents after application of different amounts of N (23, 46, 69 and 92 kg/ha) and FYM (4.6, 9.2, 13.8 and 18.4 t/ha) in different combination on different farms with no significant yield increment. This indicates although some amounts of the fertilizers could be taken up by crops, most of the fertilizers could be washed away due to soil erosion. The soil organic matter (SOM) of Gununo is totally depleted. SOM increases fertilizer use efficiency through increasing the response to mineral fertilizers and contributes nutrients to the soil. It also helps prevent soil erosion and increases soil-water retention capacity. Thus production must be improved on land that is being degraded in order to feed a growing population.

Having the problems, the farmers in the area continued cultivating the lands without trying to combat the soil erosion problem. Since the homestead areas are planted with perennial crops (Fig 1) like enset (false banana), banana, coffee, yam, taro and sweet potato, they are not affected by soil erosion as these plants cover the soil enough to reduce the detachment power of rain drops. The problem is on the outer field where cereals are mostly practiced. These parts of the farms are steepier than the homesteads and very much affected by erosion. Most of the farmers in the area perceived that erosion washes away the top fertile soil, seeds sown and applied fertilizers to down slope. But none of the farmers could control the erosion. Rather they preferred either to continue cultivating on the eroded and none protected land or leaving to other area because they could not

harvest from the degraded lands. Of course they tried to control the erosion using some indigenous management practices such as diagonal drainage ditches, shallow soil bunds (furrow) made by oxen plough and hand hoe that requires frequent maintenance, banana strips (very small number of farmers), and field boundary drainage ditches cut down the slope. But this could not be a solution rather it aggravated the washing away of the soil by increasing the force of water to lead the erosion to formation of small gully, which can be widened in the future. This caused further reduction in the arable land as no seeds can emerge on the eroded place (small gully) (Fig 2). Because of this crop yield became very much decreased from time to time, which finally reached at harvesting below the amount sown.

Looking at this problem and not getting a solution some of the farmers in the area decided to leave their farms and be engaged in off farm activities until research intervention was introduced in to the area. Soil erosion removes top soil (Fig.1), which is the richest layer of soil in both organic matter and nutrient value. Implementing soil and water conservation measures that restrict runoff and erosion minimizes nutrient losses and sustains soil productivity (Bierman and Rosen, 2005). Soil fertility improvement on sloppy lands without soil conservation is unlikely as both mineral fertilizers and organic matter applied can be lost with erosion. Therefore, this study was initiated with the objective of conserving soils by constructing soil conservation measures.

Materials and Methods

The study area is located in the southern part of Ethiopian highlands (37° 39'E, 6^o56'N) at an altitude between 1980 and 2100 m asl. The area of the watershed where the study was conducted is 544 ha. The closest major area of settlement is Sodo, approximately 24 km to the northwest. The mean maximum temperature is above 23^oC for the entire year, while the mean minimum is between 15^oC and 18^oC. The mean annual rainfall and temperature is about 1350 mm and19.5 ^oC, respectively. The topography of the area is characterized by undulating slopes divided by V-shaped valleys of seasonal and intermittent streams, surrounded by steep slopes. The rainfall is unimodal with extended growing periods from March to the end of October, with short dry spell in June. The highest rainfall is experienced during the months of July and August and causes highest soil loss. Soil fertility gradient decreases from homestead to the outfield due to management effects.

The soil conservation measures were implemented first on farms of twenty-four willing farmers to see the effect at farm level. The introduced soil conservation measures were physical structure (soil bund) and biological measures (Sesbania, Elephant grass, and Banana) by integrating the two. The soil conservation measures were implemented fully with the participation of farmers. The distance between the two soil bunds was determined by the farmers themselves. They determined the space between the two soil bunds based on the convenience to plough with oxen i.e. the land between two bunds must be wide enough to turn oxen while ploughing. The number of soil bunds to be constructed depends on the space between the bunds, size of land and the labour the farmers have to construct the bunds. Those farmers who have small farm size and shortage of labour constructed smaller number of bunds than those who have more farm size and labour. In fact all farmers constructed smaller number of bunds than required on the farms for keeping convenience of ploughing. As construction of physical soil conservation measures is labour intensive, entry points such as, provision of different crop text text varieties and seedlings of trees like *Grevilea robusta*, were used to ease the adoption. Getting good result from the farm level experiment, the experimental area was widened to watershed level to reach many farmers through collective action (by mobilizing the community). After delineation of the watershed that covers 544 ha of land and comprises five villages, a survey was conducted to identify and prioritize agricultural problems of the community. Soil erosion and fertility decline were among the top priority problems in the four villages ('Gegecho', 'Lay busha', 'Tach busha', and 'Offa' villages). After identifying that soil erosion and fertility are top priority problems, discussion was made among PAs leaders, researchers, and the community on the solution of the problems. Finally the group reached to consensus to construct soil conservation measures to solve the problems. Then soil bunds and fanya-juu were constructed and bund stabilizers (Elephant grasses) were planted on the structures

by mobilizing the farmers (collective action) who have the problems with technical leadership of researchers. Continuous participatory monitoring and evaluation (PME) was made for maintenance of the structure, improvement of soil fertility, and observation of its effect on crop yields. Soil and crop data were collected after implementation of soil conservation measures and compared with the baseline data.

Results and discussion

A total of 9965 m soil conservation structures were constructed, out of which 66.9% was Fanya-juu, 30.5% was soil bund and 2.6% was cut-off drain on farm boundaries.
Forage plants such as Elephant grass and *Sesbania sesban* were planted on the soil conservation structures as stabilizers of the structures. The soil bund stabilizing grass reduced soil losses, improved the availability of organic inputs for soil improvement, and offered animal feed and consequent increase in cash income (Tilahun Amede, 2003). These forage plants are fast growing and the farmers harvested frequently and fed their cattle. The farmers who have these forages at their homestead could not suffer from the shortage of feed as those who had not planted. The plant species also greatly contributed to the stabilization of the soil conservation structure. *Sesbania seban*, legume plant species, besides being used as bund stabilizers and feed, it was chopped and incorporated in to the soil for improvement of soil fertility.

The soil conservation measures adapted well to the local conditions and protected the soil from being eroded. Eleni Tesfaye (2008) also indicated that introduced soil and water conservation measures, fanya-juu and soil bunds, were widely acknowledged as being effective measures in arresting soil erosion and as having the potential to improve land productivity. Physical and biological soil conservation measures and soil fertility improvement activities implemented in Wolaita conserved the soil and improved soil fertility (Safene *et al.*, 2006). As a result around 1000 people living in the watershed adopted the technology. Even other farmers are also requesting for the construction of the structures, while some are copying. Waga *et al.* (2007) also indicated that improvement of soil productivity was observed within two years and farmers started constructing new structures individually. However, Farmers witnessed that their individual efforts were not successful as compared to constructing soil conservation structures with collective action (Waga *et al.*, 2007). We observed and farmers witnessed that yield increased two and more folds. The purchasing power of the farmers increased after they conserved their soil. Before the conservation of the soil, since they harvest very small yield, they ought to work in off-farm activities to buy clothes and get other services but after their soil was conserved they could able to buy the necessary things by the sell of the out puts from their farm. The soil conservation effects were seen within a year. Yield increased by 22 % on some farms and 15 fold on other farms within one year of bund construction and by >50 % after 3 years with similar farming practices. The land that could not grow any crop yielded 800 kg/ha of haricot bean after application of soil conservation measure. On 0.0625 ha of this land a well grown sweet potato could give yield that fed 7 members of a family for 3 consecutive months.
Mr. Temesgen was one of the farmers that were the most affected by soil erosion problem. The slope of his farm was more than 20 % and the top soil was totally washed away. What could be seen on the land were sub soil and the soil parent material. Crop could not be totally grown on most parts of the land. The yield (crop) he could harvest was from the homestead and down slope lands. He said that he tried to conserve his soil using some local practices but due to the steepness of his land the low efficient local practices could not improve his soil. As a result he became pessimist of the soil conservation. Finally with the help of researchers he constructed soil bunds, planted stabilizers (Elephant grasses and shrubs) (Fig 3) and did continuous maintenance. We made continuous participatory monitoring and evaluation and observed the improvement of the soil from time to time. He always praises God and us. We tried to evaluate (assess) the impact 3 years after construction. The colour of the soil is changing to black (dark), the organic matter content of the soil is increased (Table 3), which was very low before soil conservation (Table 4) and soil erosion is very much reduced (Fig 4.) (according to the farmer soil erosion is reduced by 90 %), crop yield increased (he said that yield increased by 50 %), the top soil is building-up. The farmer was very much amazed by the build up of the soil because he said that he was afraid where

to bring top soil from to fill the eroded farm. The farmer also witnessed that his living standard is improved after construction of soil conservation due to yield increment and became optimist.

Together with the soil conservation measures improved taro variety was also introduced to the watershed by researchers of Areka Agricultural research centre. As the taro produces a number of branches, it completely covers the soil and contributes to the conservation of the soil. Beside the high yielding characteristics of the taro species the conserved soil could keep the nutrients that could be washed away in the absence of the conservation measure and supply them to the crop. As a result of this, the farmers who conserved their soil and planted the taro got incredible amount of yield. Due to the higher yield they got from taro they could keep growing enset which otherwise could be used for food before maturing. Therefore, the soil conservation measures together with this high yielding variety of taro highly contributed to the survival of enset which was being lost for the farmers were using the immature enset for food.

Mr. Temesgen said that he prefers the soil conservation technology to all the other technologies introduced to the area.The farmers in the area very well perceived that the soil conservation measure protects the washing away of soil, seeds and fertilizer and thereby increases crop yield. There is no any sign of soil erosion observed on the field, the soil is built up, it became dark, retained moisture well due the construction of the soil conservation measur(Fig 4).

Though the farmers grow a number of crops in Gununo area, they obtain very low yield even with application of fertilizers. But after construction of soil conservation structures crops yields are significantly increased although the increment differs from farmer to farmer as the management of soil by different farmers is not the same (Table 2). Yield of tef was increased from 320 kg/ha to 560 kg/ha and from 300 kg/ha to 800 kg/ha on different farms. Haricot bean was increased from 180 kg/ha to 320 kg/ha, from 224 kg/ha to 368 kg/ha and from <200 kg/ha to 400 kg/ha on different farms. Yield of wheat was increased from 240 kg/ha to 320 kg/ha and from 200 kg/ha to 800 kg/ha. Maize yield was increased four folds, from 400 kg/ha to 1600 kg/ha. Potato also followed similar trend, it was increased from <400 kg/ha to 1600 kg/ha. Sweet potato, which is the major food crop of the area showed 750 % yield increment i.e. from 2400 kg/ha to 18000 kg/ha.

Conclusion

Soil degradation is the most serious problem and threat to food production, food security, and natural resource conservation in the highlands of Southern Ethiopia. As most of these lands are sloppy, soil loss due to soil erosion is very high removing all the top fertile soils, applied fertilizers, and sown seeds. Farmers are remaining with no or very low harvest when cultivating these vulnerable lands without proper management. The study clearly showed that improving the productivity of highlands, which are prone to soil erosion, without soil conservation is impossible. Therefore, construction of soil conservation measures in the degraded highlands and stabilizing with multipurpose plant species is very important to conserve the soil and increase crops yields.

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Table1. The living condition of Mr. Temesgen before and after implementation of soil conservation

Before soil conservation	After soil conservation
Very low yield (only 20 kg yield was harvested after sowing 10 kg seeds)	Increased yield (40 kg yield from 10 kg seeds)
The family was not getting enough food, he did not have ox because he could not either buy or keep calf to grow as he used to sell calf for purchasing food	The family is getting enough food (three times per day) and happy. He has ox as he could keep calf to grow up
He used to buy food items for 8 months	He now buys food items only for 4 months
The soil fertility was very low and his expenditure for fertilizer was high	The soil fertility is increased and expenditure for fertilizer is reduced by about 33 %
He could not maintain seeds due to hunger	He maintains seeds
He had no house furniture like bed, dying table, chairs etc.	He could buy bed, 3 tables and 16 chairs
He used to wear only one trousers and Jacket	He bought 3 suits and other clothes to his family

Table 2. Crop yield as significantly increased due to soil conservation

Crop	Yield before construction of soil conservation measure	Yield after construction of soil conservation measure
Teff	• 320 kg/ha • 300 kg/ha	• 560 kg/ha • 800 kg/ha (8 qt/ha)
Haricot bean	• 180 kg/ha • 224 kg/ha • <200 kg/ha	• 320 kg/ha • 368 kg/ha • 400 kg/ha

Wheat	• 240 kg/ha • 200 kg/ha	• 320 kg/ha • 800 kg/ha (8 qt/ha)
Maize	• 400 kg/ha	• 1600 g/ha (16 qt/ha)
Potato	<400 kg/ha	1600 kg/ha (16 qt/ha)
Sweet potato	2400 kg/ha	18000 kg/ha (18 qt/ha)

Table 3. Changes occurred on the soil due to soil conservation

Before soil conservation	**After soil conservation**
Removal of top soil, seeds and fertilizer by erosion	No erosion
Crop does not grow (limited crop growth)	Well growth of crops
Soil colour red, white	Soil colour black
Very low soil organic matter	High soil organic matter
Very low soil nutrients	Good (high) soil nutrients
Very low (in some farms no) yield	Good yield
Shallow top soil, on some parts of the farms sub soil was exposed	Top soil built up
Low organic matter content, 1.2 %	Increased organic matter content, 2.5 %

Fig 1.Perrenial crops completely covered the soil at the homestead of Gununo farm

Fig 2.Eroded farm at Gununo before the introduction of soil conservation measures

Fig 3. Elephant grass planted on newly constructed soil conservation structure

Fig 4. Well conserved farm in Gununo area