Lessons from Upstream Soil Conservation Measures to Mitigate Soil Erosion and its Impact on Upstream and Downstream Users of the Nile River

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Abstract

A study was conducted to evaluate the effects of soil bunds stabilized with vetiver grass (V. zizanioides) and tree lucerne (C. palmensis) on selected soil physical and chemical properties, bund height, inter-terrace slope and barley (Hordeum vulgare L.) yield in Absela site, Banja Shikudad District, Awi administrative Zone of the Amhara National Regional State (ANRS) located in the Blue Nile Basin. The experiment had five treatments that included non-conserved land (control), a 9-year old soil bund stabilized with tree lucerne, a 9-year old soil bund stabilized with vetiver grass, a 9-year old sole soil bund, and a 6-year old soil bund stabilized with tree lucerne. Data were analyzed using one-way analysis of variance (ANOVA) and mean values for the treatments were separated using the Duncan Multiple Range Test. Results of the experiment indicated that organic carbon (OC), total nitrogen (N), bulk density, infiltration rate, bund height, and inter-terrace slope are significantly ($p \leq 0.05$) affected by soil conservation measures. The non-conserved fields had significantly lower OC, total N, 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. The field treated with 9-year old soil bund stabilized with tree lucerne or sole soil bund had significantly higher OC content than all other treatments. Fields having 6-year old soil bunds had lower OC and total N when compared to fields having 9-year old soil bunds irrespective of their method of stabilization. Fields with soil bunds stabilized with vetiver grass had the highest bund height and the lowest inter-terrace slope than fields with the remaining conservation measures. Barley grain and straw yields were significantly ($P \leq 0.05$) greater in both the soil accumulation and loss zones of the conserved fields than the non-conserved (control) ones. In the accumulation zone, fields with the 9-year old soil bund stabilized with tree lucerne and those with the 9-year old sole soil bund gave higher grain yields (1878.5 kg ha^{-1} and 1712.5 kg ha^{-1}, respectively) than fields having 9-year old soil bund stabilized with vetiver grass (1187 kg ha^{-1}) and 6-year old soil bund stabilized with tree lucerne (1284.25 kg ha^{-1}). When we compare the accumulation and the loss zones, the average grain yield obtained from the accumulation zones (averaged over all the

treatments) was 29.8% higher than the average grain yield obtained from the loss zones. The causes of soil erosion in the region could be the rugged 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. From the study it was possible to conclude that soil bunds stabilized with vegetative measures (such as tree lucerne and vetiver) better held the soil in-situ and improve inter-terrace soil physical and chemical properties compared to the non-conserved fields. This suggests that by applying soil conservation measures upstream, the erosion rate will be minimized and the amount of silt entering streams and ultimately the Blue Nile River will be minimized. This, in turn, will significantly improve land productivity in the upstream areas and cut the huge costs of silt cleaning in the dams and irrigation canals of the downstream countries that use the Blue Nile River.

Introduction

Soil degradation can be described as a reduction of resource potential by or on a combination of processes acting on the land, such as soil erosion by water and wind, bringing about deterioration of the physical, chemical and biological or economic properties of soil (Maitima and Olson, 2001). The principal environmental problem in Ethiopia is land degradation, in the form of soil erosion, gully formation, soil fertility loss and severe soil moisture stress, which is partly the result of loss in soil depth and organic matter (Fitsum et al., 1999). The excessive dependence of the Ethiopian rural population on natural resources, particularly land, as a means of livelihood is a underlying cause for land and other natural resources degradation (EPA, 1998)

Some forms of land degradation are the result of normal natural processes of physical shaping of the landscape and high intensity of rainfall. The scale of the problem, however, dramatically increased due to the increase in deforestation, overgrazing, over-cultivation, inappropriate farming practices, and increasing human population. Removing vegetative cover on steep slopes (slopes ranging between 15 and 50 percent) for agricultural expansion, firewood and other wood requirements as well as for grazing space has paved the way to massive soil erosion. Forest cover in the Ethiopian highlands as a whole decreased from 46% to 2.7% of the land area between the 1950's and the late 1980's. This is compounded by increasing numbers of livestock being forced on to shrinking pastures (Esheteu *et al*., 2006). According to Esheteu *et al*. (2006), although about 82% of the rural household energy is covered by fuel wood and supplemented by dung (about 9%) and burning of crop residues (about 8%), the land tenure and tree tenure have provided little incentive for protection of forests and tree planting.

It is estimated that over 1900 million tons of soil are lost from high lands of Ethiopia annually (EHRS, 1986). These losses of productive topsoil are irreversible for it takes many years to generate a ton of topsoil. The Ethiopian highlands, which are the center of major agricultural and economic activities, have been the victim of soil erosion for many years. It is concluded that about half of the highland's land area (about 27 Million hectares) is significantly eroded and over one-fourth (14 Million hectares) are seriously eroded. Moreover, 2 Million ha of land is permanently degraded that the land is no longer able to support cultivation (EHRS, 1986).

In the Amhara region, the soil loss due to water erosion is estimated to be 58% of the total soil loss in the country (Tesfahun and Osman, 2003). This has already resulted in a reduction in agricultural productivity of 2 to 3% per year, taking a considerable area of arable land out of production. The situation is becoming catastrophic because increasingly marginal lands are being cultivated, even on very steep slopes (Tesfahun and Osman, 2003).

To mitigate land degradation problems in Ethiopia, the government has taken different soil and water conservation measures. Nevertheless, the rate of adoption of the interventions is considerably low. Space occupied by soil and water conservation (SWC) structures, impediment to traditional farming activity, water logging problems, weed and rodent problems, huge maintenance requirement, are some of the reasons that cause farmers refrain from SWC works. In addition, top down approach in the extension activity, focusing mainly on structural soil and water conservation technologies, and land security issues contribute much to the failure of SWC works (Mitiku *et al*., 2006). The present study was conducted on one of the few successful SWC structures stabilized with biological measures to investigate the effects of integrating physical and biological conservation on some soil physical and chemical properties of the soil and subsequently on yield of crops and its implication on downstream inhabitants.

Materials and methods

Description of the study Area

The study area is located in Absela Kebele, Banja Shikudad Woreda, Awi Zone of the Amhara National Regional State (ANRS) between $10^o45'$ N – $10^o48'$ N latitude and $37^o03'$- $37^o04'$E longitude. The mean annual rainfall of the study area ranges from 1700 mm to 2560 mm, with mean monthly minimum and maximum temperature ranging from 7^oC to 12^oC, and 20^oC to 25^oC, respectively. The area has wet-cold locally known as *wet dega* agro-climatic zone (RELMA *et al.*, 2005). The study area has an altitude that ranges between 2220 and 2600 meters above sea level with undulating topography. Its slope ranges from 15% to 25%. The total area of the catchment that was treated with different type of soil and water conservation measures is about 126 ha. The length of growing period of the study area ranges between 240 and 270 days (EMA, 1982). The farming system of the area is mixed farming, which includes crop such as barley, wheat, teff, pulse crops, and livestock (mainly sheep and cattle).

Characterization of the SWC structures considered in the study

All soil and water conservation measures in the catchment area were installed for the purpose of demonstration; to diffuse extension service related to natural resource conservation to the farming community by the district and zonal agricultural bodies. The catchment area was delineated and various soil and water conservation activities were practiced since 1998. Various ages of soil bund stabilized with vegetative measure such as vetiver grass (*V. zizanioides*), tree lucerne (*C. palmensis*), sesbania (*Sesbania sesban*) and phalaris grass (*Phalaris spp.*) are found in the catchment. The catchment area was kept under close supervision by the woreda agricultural office and two guards were instantly assigned after the start of the watershed work.

The study site had original slope of 21% (slope percent prior to the construction of the structures) and 2m vertical interval were used for the spacing of bunds. All the soil bunds were constructed in such a way that a trench was excavated along a contour at 1% gradient towards the water way and the soil was thrown down hill.

Experimental design and layout

The experiment contained five treatments, which includes:

1. Control (non-conserved plots)
2. 6 years Soil bund + tree lucerne
3. 9 years Soil bund + tree lucerne
4. 9 years Soil bund + vetiver
5. 9 years Soil bund

Determinations of Soil Physical and Chemical Properties

For each treatment, a composite soil samples were collected from a 10 x 3m sampling plot using simple random sampling technique from four consecutive inter-terraces space at the deposition zone.

Soil organic carbon (SOC) was determined following the wet digestion method used by Walkley and Black (Sahelemedhin and Taye 2000). Organic matter was computed from organic carbon by multiplying each value of SOC by 1.724. Total Nitrogen was determined by Kjeldahl method (Sahelemedhin and Taye 2000).

The soil bulk densities were determined from the oven dry (at 110^{o}C for 24 hrs) mass of soil in the core sampler and volume of the undisturbed soil cores using core sample method (Landon, 1991) and infiltration rate was measured using double ring infiltrometer.

Results and discussion

1. Effect of Soil Conservation Measures on Soil Chemical and Physical Properties

Organic matter

Results of the experiment indicated that there was highly significant ($p \leq 0.05$) difference in OM content among the treatments. The treatments with 9-year old soil bund stabilized with tree lucerne and the 9-year old sole soil bund were not statistically different among each other. However, they have significantly higher organic matter (OM) content than that of the 9-year old soil bund stabilized with vetiver, the 6-year old soil bund stabilized with tree lucerne, and the non-conserved treatments. Although the 9-year old soil bund stabilized with vetiver had statistically lower percent OM than the sole 9-year old soil bund treatments, it was superior and had significantly ($p \leq 0.05$) highest percentage of OM than the 6-year old soil bund stabilized with tree lucerne, and the non-conserved treatment (Table 1). This indicates that years of bund establishment play a tremendous role in OM accumulation.

Table 2 Effect of SWC measures on organic matter content of the soil

Treatments	**Organic matter (%)**
Control (Non-conserved land)	1.577^{d}
6-yrs old soil bund + tree lucerne	2.470^{c}
9-yrs old soil bund + tree lucerne	5.017^{a}
9-yrs old soil bund + vetiver	3.306^{b}
9-yrs old soil bund	5.478^{a}
CV (%)	14.00
$SE_{\bar{x}}$	0.249

Means in a column followed by the same letter are not statistically different at $p \leq 0.05$

The non-conserved plots had the lowest mean value of OM than all other treatments considered in the study. Relatively the 9-year old soil bund, the 9-year soil bund stabilized with tree lucerne, the 9-year old soil bund stabilized with vetiver, and the 6-year old soil bund stabilized with tree lucerne had 71.20, 68.56, 52.30, and 36.12%, respectively higher percent OM than the control treatment. The result agrees with the finding by Million (2003) who found that organic matter content of three terraced sites with original slopes of 15, 25, and 35 % were higher compared to the corresponding non-terraced sites of similar slope. A study conducted by Kinati (2006) in the Amhara region, Enebsie Sar Mider woreda, also showed that the organic matter content of non-conserved land for a slope range between 10 and 15% were lower (mean = 1.12%) than the terraced land of corresponding slope class (mean=2.33%).

According to Bot and Benites (2005), organic matter accumulation is often favored at the bottom of hills for two reasons: one is they are wetter than at mid- or upper slope positions, and the other is organic matter would be transported to the lowest point in the landscape through runoff and erosion. The same holds true for terraced land where soils are actively eroded from the soil loss zone and deposited to the soil accumulation zone, creating spatial variability in terms of moisture and nutrient availability within the inter-terrace space.

Total nitrogen

Results of the experiment presented in Table 6 revealed that the mean total N difference due to treatment effect were significant ($p \leq 0.05$). Even though the 9-year old soil bund stabilized with tree lucerne and the 9-year old soil bund are statistically non-different in the mean value of total nitrogen, both were significantly ($p \leq 0.05$) higher than the 6-year old soil bund stabilized with tree lucerne, the 9-year old soil bund stabilized with vetiver and the non-conserved treatment. It was clearly seen that the non-conserved plot had the smallest mean value of total nitrogen (Table 2).

Table 3 Effect of SWC measures on total nitrogen content of the soil

Treatments	Total nitrogen (%)
Control (Non-conserved land)	0.125^{c}
6-yrs old soil bund + tree lucerne	0.173^{bc}
9-yrs old soil bund + tree lucerne	0.277^{a}
9-yrs old soil bund + vetiver	0.215^{b}
9-yrs old soil bund	0.284^{a}
CV (%)	17.48
$SE_{\bar{x}}$	0.0187

Means in a column followed by the same letter are not statistically different at $p \leq 0.05$

Million (2003), also found that the mean total N content of the terraced site with the original slope of 15, 25, and 35% were higher by 26, 34, and 14%, respectively compared to the average total N contents of their corresponding non-terraced slope. A simple linear regression analysis showed a strongly positive relation between total nitrogen and organic carbon (R^2 =0.88)

Bulk density

The one-way analysis of variance revealed the presence of significant difference ($p \leq 0.05$ and R^2 = 0.75) in mean value of bulk density among the treatments. The non-conserved treatment was found to exhibit significantly the highest mean value of bulk density than the remaining treatments. The result also showed non-significant difference in mean value of bulk density among other treatments, which were managed through a range of conservation measures irrespective of the establishment year. In this study, the relatively lower bulk density associated with treatments conserved with various measures (Table 3) could be attributed to the presence of significantly ($p \leq 0.05$) higher content of organic matter in those treatments.

Table 4 Effect of SWC measures on soil bulk density

Treatments	Soil bulk density (g cm^{-3})
Control (Non-conserved land)	1.38^{a}
6-yrs old soil bund + tree lucerne	1.26^{b}
9-yrs old soil bund + tree lucerne	1.29^{b}
9-yrs old soil bund + vetiver	1.25^{b}
9-yrs old soil bund	1.27^{b}
CV (%)	2.43
$SE_{\bar{x}}$	0.015

Means in a column followed by the same letter are not statistically different at $p \leq 0.05$

Infiltration rate

The one-way analysis of variance revealed the presence of statistically significant difference ($p \leq 0.05$, $R^2 = 0.66$) in mean value of infiltration rate among the treatments. The 9-year old soil bund and 9-year old soil bund stabilized with tree lucerne had the highest mean value of infiltration rate than the other treatments. The non-conserved treatment had lowest mean value of infiltration rate (Table 4).

Table 4 The effect of treatments on infiltration rate

Treatments	Infiltration rate (cm hr^{-1})
Control (Non-conserved land)	0.24^{b}
6-yrs old soil bund + tree lucerne	0.28^{b}
9-yrs old soil bund + tree lucerne	0.73^{a}
9-yrs old soil bund + vetiver	0.82^{a}
9-yrs old soil bund	0.88^{a}
CV (%)	44.80
$SE_{\bar{x}}$	0.109

Means in a column followed by the same letter are not statistically different at $p \leq 0.01$.

The organic matter and percentage of clay soil separates in the treatments seemed to play the crucial role for the variation in mean basic infiltration rates. The organic matter was positively correlated ($p \leq 0.01$; $R^2 = 0.55$) with the infiltration rate and while clay percentage was negatively correlated ($p \leq 0.01$; $R^2 = 0.52$) to the same. Moreover, infiltration rate negatively correlated with bulk density of the soil. According to the rating of Landon (1991), the non-conserved, the 6-year soil bund stabilized with tree lucerne had slow infiltration rate while the 9-year soil bund treatment, the 9-year old soil bund stabilized with tree lucerne and the 9-year soil bund stabilized with vetiver treatments and had moderately slow infiltration rate.

Effect of Soil Conservation Measure on Slope Transformation

Results of the experiment indicated that the mean values of inter-terrace slope (Table 5) for the treatments were found to be significantly different ($p \leq 0.05$ and $R^2 = 0.98$). The 9-year old soil bund stabilized with vetiver had significantly the lowest inter-terrace slope than all other treatments considered in the study signifying the effectiveness of vetiver grass in bund stabilization and slope transforming ability when compared to the other bund stabilization techniques.

Differences in year of bund installation also brought a variation in inter-terrace slope, which was realized by having a lower inter-terrace slope for the aged bund than the younger one. Therefore, all 9-year old soil bund treatments (irrespective of bund stabilization technique) had the lowest mean value of inter-terrace slope percent than the 6-year old soil bund stabilized with tree lucerne. Considering age of bunds and the type of material used to stabilize them, the 9-year soil bund stabilized with tree lucerne also had significantly lower inter-terrace slope than the 6-year old soil bund stabilized with similar method.

The deposition of soil materials and debris on the upper position of soil bund (usually called accumulation zone) causes the height of the bunds to rise year after year, thereby reducing the inter-terrace slope between two successive structures.

Similar to inter-terrace slope, the mean value of bund height were also affected by age of the bunds. The older the bund the higher was its bund height. Thus, the 9-year old soil bund treatments had higher mean bund height than the 6-year old soil bund. Karl and Ludi (1999) pointed out that in the course of erosion process that forms the terrace, the topsoil below the structure would gradually move down a slope and accumulate above the next SWC structures. This would eventually increase the bund height in gradual processes. According to Desta *et al.* (2005), the rate of sediment accumulation by bunds is correlated with the soil loss by tillage because all the soils displaced by tillage remains in the accumulation zone.

Table 5 Effect of SWC measures on inter-terrace slope

Treatment	Inter-terrace slope (%)	Bund height (cm)
Control (Non-conserved land)	21.00[a]	0.00[c]
6-yrs old soil bund + tree lucerne	17.50[b]	61.50[b]

9-yrs old soil bund + tree lucerne	14.00^{c}	67.50^{b}
9-yrs old soil bund + vetiver	10.25^{e}	100.75^{a}
9-yrs old soil bund	12.75^{d}	68.00^{b}
CV (%)	3.96	9.11
$SE_{\bar{x}}$	0.30	2.78

Means in a column followed by the same letter are not statistically different at $p\leq0.05$

Effect of the Conservation Measures on Barley Yield

The one-way analysis of variance computed for the various treatments showed that the grain yields were found to vary significantly ($p\leq0.05$ and $R^2 = 0.96$). The 9-year old soil bund stabilized with tree lucerne was found to give significantly ($p\leq0.05$) higher mean value of grain yield than the 9-year old soil bund, 9-year old soil bund stabilized with vetiver, 6-year old soil bund stabilized with tree lucerne and the non-conserved treatment (Table 6). Although it was not significant, the 9-year old soil bunds stabilized with tree lucerne had higher grain yield that the 9-year old soil bund treatment. The non-conserved treatment had significantly lower mean value of grain yield compared to all other treatments, which were treated with various kinds of conservation measures. The straw yield and other yield components also showed similar trend in performance as that of the grain yield at the deposition zone.

Table 6 Effect of conservation measures on grain and straw yield, and yield components at the soil deposition zone

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	No. of Plants m^{-2}	No. of Spikes m^{-2}	No. of spikelets/ spike	Plant height (cm)
Control (Non-conserved land)	561.25^{d}	622.75^{c}	350^{c}	404^{b}	7.0^{c}	44.50^{c}
6-yrs old soil bund + tree lucerne	1284.25^{c}	1233.75^{ab}	397^{ab}	431^{b}	15.75^{b}	57.75^{b}
9-yrs old soil bund + tree lucerne	1878.75^{a}	1480.00^{a}	426^{a}	478^{a}	18.25^{a}	75.75^{a}
9-yrs old soil bund + vetiver	1187.50^{c}	957.50^{b}	396^{ab}	417^{b}	16.00^{b}	69.00^{ab}
9-yrs old soil bund	1712.50^{b}	1473.50^{a}	375^{bc}	435^{b}	17.25^{ab}	77.75^{a}
CV (%)	7.82	16.47	6.55	5.79	7.01	11.5
$SE_{\bar{x}}$	51.80	95.01	12.73	12.52	0.52	3.74

Means in a column followed by the same letter are not statistically different at $p\leq0.05$.

Higher yield associated with the conservation measures could be attributed to the presence of high level of organic matter and total nitrogen in these treatments. A regression analysis computed for the grain yield performance with organic matter and nitrogen had confirmed this fact. Organic carbon and total nitrogen were directly related

($p \leq 0.01$; $R^2 = 0.74$, and $p \leq 0.01$; $R^2 = 0.71$, respectively) to the grain yield of barley. Yield obtained from the accumulation zone of the conserved land were significantly higher than the loss zone. This signifies the presence of fertility gradient within the inter-terrace space and highest yield in the deposition zone of the conserved treatments seemed to associate with the level of OM and total nitrogen contained in the same, coupled with other desirable changes in soil physical and chemical brought by the implemented conservation measures at the spot (Table 7).

Table 7 Effect of conservation measures on grain and straw yield, and yield components at the soil loss zone

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	No. of plants m^{-2}	No. of spike m^{-2}	No. of spiklets/ spike	Plant height (cm)
Control (Non-conserved land)	561.25^{c}	622.75^{c}	350^{a}	404^{a}	7.00^{c}	44.5^{c}
6-yrs old soil bund + tree lucerne	944.25^{b}	875.50^{b}	341^{a}	373^{a}	11.50^{b}	53.0^{b}
9-yrs old soil bund + tree lucerne	1199.50^{a}	1084.75^{a}	337^{a}	365^{a}	14.75^{a}	64.5^{a}
9-yrs old soil bund + vetiver	949.25^{b}	907.00^{b}	338^{a}	357^{a}	11.50^{b}	54.5^{b}
9-yrs old soil bund	1166.00^{a}	978.25^{ab}	322^{a}	338^{a}	15.50^{a}	58.5^{ab}
CV (%)	10.08	9.27	8.84	7.56	11.29	8.08
$SE_{\bar{x}}$	48.59	41.41	14.91	13.88	0.68	2.22

Means in a column followed by the same letter are not statistically different at $p \leq 0.05$.

Causes of Soil Erosion in the ANRS of Ethiopia

Soil erosion is becoming a serious problem in Northwestern Ethiopia where the Blue Nile starts. The main causes of the problem could be:

a) Natural factors

The area is characterized by rugged and sloppy topography which causes the intensity of erosion to be very high. Mountains cover 52% of Asia, 36% of North America, 25% of Europe, 22% of South America, 17% of Australia and 3% of Africa. As a whole, 24% of the Earth's land mass is mountainous. Nevertheless, of the 3% of African mountains, Ethiopia takes 60% (Wikipedia, 2006). In Ethiopia, about 44% of the land area (>1500 m asl) has typical highland characteristics. Contrary to the country's average, the highland part in the Amhara Region is about 70%.

b) High and erratic rainfall pattern.

The western highlands of the Amhara National Regional State receive heavy rainfall that in some places reaches well above 2000 mm. All the rainfall falls in few months time that does not usually exceed 4 months. This situation causes excessive land slide and erosion.

c) Extensive deforestation

The natural forest cover in 1962 was 40% of the country's total area. Now the forest cover is only 2.7%. It is estimated that from 150,000-200,000 hectares of forest are destroyed every year.

d) Continues cultivation and complete removal of crop residues from the field.

Due to the small land holding per household (<1ha in Northwestern Ethiopia), there is a practice of continues cultivation without replenishing the land with appropriate amount of input. Moreover, farmers remove the residues for animal feed, plastering of their houses and fuel energy source.

e) Over and free grazing.

Ethiopia has the largest livestock population in Africa. This livestock population grazes in uncontrolled grazing system on mainly communal lands. Eventually, livestock productivity is one of the lowest in Sub-Saharan Africa. In such situation, neither the land nor the livestock are benefited.

f) Improper farming practices and development efforts.

Farmers use a 3000 years old farming practices that does not protect the land and. Moreover, huge amount of lands are washed away by road side drainage canals. However, there is no accountability for damage made on the land.

g) Over population

The Amhara National Regional State (ANRS) with the area of 157,076.52km^2 has a population of about 19,122,515 and the population density of the land is 121.7 persons km^2. From the total population, 85% is dependent on agriculture and the average land holding per household is less that a hectare. Unlike most of the world's hotspots of civilization, situated around river deltas and downstream places, centre of economic and political activities in Ethiopia is peculiarly situated in the mountain system where land resources are sensitive to degradative agents and where the resources support immense economic and ecological functions to both upstream and downstream riparian countries. Compared with the average population pattern of settlement of the world that is 1 out of 10 people lives in mountain areas, in Ethiopia, it is estimated that 9 out of 10 people or about 90% of the total population live in the highlands (Biru Yitaferu, unpublished data).

h) Socio- economic problems

Ethiopian farmers lack alternative livelihoods except agriculture and have poor socio-economic conditions. The per capita income of the region is only $92/annum and 30% of the population lives below poverty line (BoI, 2005).

i) Lack of awareness on the effect of erosion

The farmers lack of awareness on effects of erosion and they do not realize that erosion is the main cause of yield reduction year after year.

j) Poor land use policy enforcement.

The ANRS has land use policy. Nevertheless, the policy never been properly implemented. Farmers also do not take accountability for the damage they make on their lands due to violating land use policies

Conclusions and recommendations

From the results of the experiment it is possible to conclude the following:

1) The experiment confirmed the presence of heavy erosion in the Ethiopian highlands;
2) It was clearly seen that by implementing integrated soil and water practices, it is possible to significantly reduce soil erosion;
3) Upstream soil conservation practices can improve land productivity and increase yield;

4) Upstream soil and water conservation practices can make the rainwater to infiltrate in to the soil. This eventually will recharge the groundwater, and rivers and streams will have higher volume of discharges;
5) Upstream soil and water conservation practices will minimize sedimentation of dams, reservoirs, rivers and destruction of agricultural lands.

From the results of the experiment it is possible to recommend the following: In the upstream there is a need to take the following measures:

1) Rehabilitate degraded lands through
   - Improved SWC practices (Integrate physical and biological measures)
   - Practicing area closure and tree plantation schemes on sloppy lands
   - Delivering alternative fuel energy sources
2) Improve land productivity and reduce area under cultivation (steep slopes) by using
   - Improved seed
   - Integrated nutrient management
   - Integrated pest management
   - Improved agronomic and land management practices
3) Practice stall feeding (better feed supply and quick economic return)
4) Reduce pressure on the farm lands by providing alternatives to the rural community other than agriculture
4) Implement the land use policy
5) Improve awareness of the farmers on effects of erosion
6) Expand education and health services

The downstream countries could financially and technically support the upstream efforts

1) Training and research;
2) Establishment of fertilizer and pesticide factories that will improve land productivity and enclose mountains from annual crop production;
3) Invest in the agricultural processing, industry and urban sectors to minimize the pressure on mountain lands.

These joint efforts will minimize erosion rate and the amount of silt entering streams and ultimately the Blue Nile will be minimized. This in turn will significantly improve land productivity in the upstream and will cut the huge costs of silt cleaning in the dams and irrigation canals of the downstream countries using the Blue Nile.

References

BoI. 2005. Annual Information book for 2008 E.C (In Amharic). Bureau of Information (BoI), Amhara National Regional State, Bahir Dar.

Desta, G., 2003. Effectiveness And Sustainability of Soil and Water Conservation Bunds on Cropland in the Tigray Highlands, Northern Ethiopia, M Sc Thesis, Katholieke University Leuven , Faculteit Wetenschappen, Eepartment Geografie-GeologieEHRS, 1986

EMA, 1982. The Length of the Growing Period in Ethiopia. PMGSA-MoA-Land Use

Planning and Regulatory Department/UNDP-FAO Assistance to Land Use Planning Project-ETH/78/003, Addis Ababa, Ethiopia.

EPA, 1998. National Action Programme to Combat Desertification, Federal Democratic Republic of Ethiopia Environmental Protection Authority, Addis Ababa NOVEMBER 1998158

Esheteu Bekele, Ferdu Azerefegne, and Tsedeke Abate 2006. Facilitating the Implementation and Adoption of Integrated Pest Management (IPM) in Ethiopia. Planning workshop from October 13-15th 2003 at the Melkassa Agricultural Research Center, EARO; Jointly organized by the Association for Advancement of IPM (ASAI) and the Ethiopian Agricultural Research Organization (EARO); DCG (Drylands Coordination Group) Proceedings No. 17. 158pp

Fitsum Hagos, John Pender and Nega Gebreselassie,1999. Land Degradation in the Highlands of Tigray and Strategies for Sustainable Land Management. Livestock Policy Analysis Project; International Livestock Research Institute, Addis Ababa.

Kinati, C., 2006. The Effect of Integrated Soil and Water Conservation Measures On Soil Physical and Chemical Properties, A Case For Enebsie Sar Midir Wereda, Ethiopia. A Thesis Paper, Mekelle University, Mekelle.

Landon , J.R., 1991. Booker Tropical Soil Manual. A Handbook for Soil Survey and Agricultural Land Evaluation in Tropics and Sub Tropics. Longman Scientific and Technical Publishers, New York, 106-156

Maitima, J.M., J M. Olson , 2001. Guide to field methods for comparative site analysis for the Land Use Change, Impacts and Dynamics (LUCID) Project Working Paper Series Number: 15. Nairobi, Kenya: International livestock Research Institute.

Million, A., 2003. Characterization of Indigenous Stone bunding (Kab) and its effect on crop yield and soil productivity at Mesobit-Gedba, North Showa Zone of Amhara Region. Thesis, Alemaya University.

Mitiku , H., K. Herweg , B. Stillhardt, , 2006. Sustainable Land Management- A New Approach to Soil and Water Conservation in Ethiopia. Mekelle, Ethiopia: Land resources Management and Environmental Protection Department, Mekelle University; Bern, Switzerland: Center for Development and Environment (CDE), University of Bern and Swiss National Center of Competence in research (NCCR) North-South. 269p

Nyssen , J., J. Poesen, Mitiku H., J. Moeyersons, J. Deckers .2000. Tillage erosion on slopes with soil conservation structures in the Ethiopian highlands. Soil &Tillage Research 57: 115-127.

Sahelemedhin Sertus and Taye Bekele 2000. Procedures for soil and Plant analysis. Technical paper no. 74. National Soil Research Center, Ethiopia Agricultural Research Organization, Addis Ababa, Ethiopia

Tesfahun, F., and Osman A., 2003. Challenge and prospects of Food security in Ethiopia. Proceeding of the Food Security Conference 2003., UNNCC, Addis Ababa , August 13-15,2003.

Wikipedia, 2006. Mountain. The free encyclopedia.htm, last modified 21:01, 17 October 2006