Cost benefit analysis of soil conservation measures: the case of Blue Nile basin

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Abstract

This study estimates the onsite costs and benefits of soil conservation measures in the upper Blue Nile basin and the associated offsite costs of soil erosion in the downstream part of the basin with a particular emphasis on the Gezira irrigation scheme in Sudan. The estimation of the onsite cost and benefit shows that soil and fanya juu bunds are financially attractive conservation measures in Gozamn and Senan woredas. The cost and benefit comparisons made at the upper Blue Nile basin and the Gezira scheme discloses that the damage cost in the Gezira scheme outweighs the investment cost of the measures in the Upper Blue Nile basin suggesting the benefit of conserving the upper Blue Nile basin in order to reduce the offsite costs of erosion at the Gezira irrigation scheme. The study concludes that implementation of conservation measures taking into account all the success factors reduce soil erosion and benefit farmers. Moreover, a coordinated effort between Ethiopia and Sudan may reduce the offsite cost of erosion.

Key words: Cost benefit analysis**,** Onsite and offsite costs, Soil erosion, Blue Nile basin, Gezira irrigation scheme, Ethiopia, Sudan

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Introduction

Ethiopia provides a well known example of a severely degraded African environment with the consequent implications for low and declining agricultural productivity (Campbell, 1991). Ethiopia's inherently fragile soils, undulating terrain, highly erosive rainfall and the environmentally destructive farming methods that many farmers practice coupled with high population density make it highly vulnerable to soil erosion (Grepperud , 1994; World Bank, 2008). In Ethiopia soil erosion is greatest on cultivated land, where the average annual loss is 42 tons/ha, compared with 5 tons/ha from pastures. As a result, nearly half the soil loss comes from land under cultivation (Hurni, 1988). The on-site effects of land degradation on agricultural land are a major source of concern since they threaten the sustainability of agricultural production and the welfare of a substantial portion of the country's population. In addition to affecting the productivity of the land directly (on-site effects), the soil and excessive runoff that leave the boundary of individual farms cause off-site or off-farm impacts and result in costs or benefits that are external to the farm household. In particular, soil erosion causes economic damage to reservoirs, irrigation schemes, waterways and flood risks downstream (Pagiola, 1999; NBI, 2007). Such costs are usually not internalized by upstream land users and affect downstream resource users. A case in point is the sedimentation of the Gezira irrigation scheme in Sudan which is a result of massive erosion from the Upper Blue Nile river basin. The severe erosion in the upper catchments of the Abay has impacts downstream within and across political borders.

Efforts have been made to launch soil and water conservation programs in Ethiopia in order to overcome the problem of soil erosion by water. The main objective of this study is to analyze the costs and benefits of soil conservation measures in the Upper Blue Nile river basin in Ethiopia and the avoided damage cost of sedimentation in the Gezira irrigation scheme in Sudan. The study will suggest feasible solution to policy makers both in Ethiopia and Sudan to reduce the onsite and offsite costs of soil erosion in the Blue Nile basin. The paper proceeds as follows; the next section presents review of literature on the costs and benefits of soil conservation measures in the highlands of Ethiopia. Section 3 deals with description of the study area, methodology and data. In section 4 the result of the cost benefit analysis and the offsite cost will be discussed. Section 5 concludes and provides recommendations.

2. Literature review

This review focuses on the costs and benefits of soil and water conservation measures particularly soil bund, stone bund and fanya juu in the highland of Ethiopia. The review helps to take stock of the existing information and to give an overview of the relevance of the problem most importantly in the highly degraded highland part of Ethiopia.

Kassie et al. (2007) reported the result of a study conducted in the high and low rainfall areas of the Ethiopian highlands particularly the Amhara and Tigray regions respectively where they investigated the impact of stone bund on crop production value per hectare. The study used random effect model, stochastic dominance analysis and matching methods to ensure robustness and to control for selection and endogeneity biases that may arise due to correlation of unobserved heterogeneity and observed explanatory variables. The finding of the study in all the three methods consistently indicated that plots with stone bunds are more productive than those without such technologies in semi-arid area but not in higher rainfall areas. The study further explained that the moisture conserving benefit of stone bunds are more significant in drier areas implying that the performance of stone bunds varies by agro-ecological type. In a related study Kassie et al. (2008) measured the impact of fanya juu bunds on the value of crop production in the northwestern Ethiopian highlands using cross-sectional multiple plot observations. The study applied a similar methodology as mentioned above to ensure robustness and control for selection and endogeniety. They reported that in all the three models they found a consistent story that the value of crop production for plots with fanya juu bunds was lower than for plots without bunds. In addition, the yield decomposition results showed that, although there was little difference in endowments between conserved and unconserved plots, the returns to endowments were substantially higher for unconserved plots. The study suggests that, it is hard to avoid the conclusion that these technologies might reduce soil erosion and associated off-site effects, but they did so at the expense of poor farmers in the Ethiopian highlands. The study concluded that unless productivity is increased, for example, by increasing fodder grass production on bunds, fanya juu bunds reduce on-farm production and therefore could not be characterized as a "win-win" measure to reduce soil erosion.

A cost benefits analysis by Shiferaw and Holden (2001) in the highlands of the Amhara region estimated the damage function from soil erosion and evaluated the profitability of conservation investment. The study found out that, economic gains to small farmers by switching from traditional land management to soil-conserving practices under the existing production technologies are minimal, only investments in grass strips seemed to provide sufficient economic incentives to small farmers. The reason for low returns to proposed conservation options are explained by the study as the yield penalty due to area loss and high investment costs. The study recommended focusing on minimizing the area loss effect and subsidizing the initial investment costs as an incentive to farmers to conserve soil moreover supporting low cost technologies that provide short term benefits to poor farmers is suggested as a short tem policy option.

Ludi (2002) also conducted a cost benefit analysis of soil bund and stone bund in the highlands of the Amhara regional state taking in to account the fact that soil erosion cannot be entirely controlled even with introduced soil conservation, slope-specific combination of yields in relation to the conservation structures and the land occupied by conservation structures in its true extent, that is, soil depth, slope gradient, and conservation technology. As a consequence, the study results show that total yields from conserved fields are often smaller than yields from unconserved fields, especially in the first years. In those situations where soil loss rates and the effect of decreasing soil depth on the yield are low, yields from unconserved fields remain higher than yields from conserved fields even after a long period.

A couple of other studies conducted in the moisture stressed highland parts of the country, however, reported success stories. Bekele (2005), for example, analyzed the benefit of investing in soil and water conservation structures in terms of higher yield and return or less variability in yield or return to subsistence farmers in the eastern highlands of Ethiopia. The study compared net return from crop production with and without soil and water conservation based on stochastic dominance criteria. The result of the study indicated that adopting a conservation strategy resulted in a higher grain yield and net return than in not adopting. The study added that appropriate policy that encourage farmers to adopt soil and water conservation measures will contribute to improving the welfare of subsistence farm households in the study area and area with a similar settings. Similarly, Gebremedhin et al. (1999) has also conducted a field experiment to analyze the effect of stone terraces on crop yield and farm profitability in the northern part of the country. The study examined 70 terraced and 70 non conserved plots with wheat and faba beans. The result of the experiment indicated that grain and straw yield were significantly higher in the soil accumulation zone than in the soil loss zone or in the non-terraced control plots; grain and straw yield from the soil accumulation zone were more stable than those from control zone. The study disclosed that over a 30-yr planning horizon, stone terraces yielded a 50% rate of return.

To summarize, soil erosion is causing huge loss in terms of degrading the semi-renewable soil resource of the country and reducing crop yield. This is an indication of the severity of the problem and the urgent need for solution. Conservation measures particularly soil bund, stone bund and fanya juu are widespread in the highlands of the country as a solution to curb soil erosion by water even though the success is limited. From the literature review conducted it is identified that all of the studies mainly focused on the onsite costs and benefits of soil erosion and conservation measures. As far as the authors' knowledge is concerned no study analyzed the offsite or the downstream damage of soil erosion. Therefore, in this study in addition to estimating the costs and benefits of soil conservation measures at the household level and at the Upper Blue Nile basin level a particular emphasis will be given to the offsite costs of soil erosion and avoided damage costs of the Gezira irrigation scheme in Sudan. In this way this study tries to fill the gap of the upstream and downstream costs and benefits of soil erosion and conservation measures.

3. Study area

The Upper Blue Nile basin is the largest river basin in terms of volume of discharge and second largest in terms of area in Ethiopia and is the largest tributary of the Main Nile. It comprises 17 percent of the area of Ethiopia (176 000 km2 out of 1 100 000 km2), where it is known as the Abay. The basin drains a large portion of the central and south-western Ethiopian Highlands. The soils generally consist of latosols on gentle slopes and deep vertisols in flatter areas subject to waterlogging. The elevation of the basin range from roughly 500 to 4050 meter above sea level and this has a major influence both on the climate and human activities. The traditional classification of climate is based on elevation and recognizes three zones: (1) the Kolla zone below 1800 meters with mean annual temperatures of 20-28^{0}C (2) the Woina Dega zone between 1800 and 2400 meters with mean annual temperatures of 16-20^{0}C (3) the Dega zone above 2400 meters with mean annual temperatures of 6-16^{0}C (Conway, 2000).

Rainfall ranges from nearly 2,000 mm/yr in the Ethiopian Highlands to less than 200 mm/yr at the junction with the White Nile. The highest rainfall values are recorded on Mount Choke to the south of Lake Tana and on the mountains south of the Abay River. Within the highlands of Ethiopia, a uni-modal wet season is found to the west of the Simien massif. The wet season lasts about four months, from June to September. East of the Abay the rainfall pattern is bi-modal, characterized by two wet seasons. The “*Belg*”, or short rainy season, occurs from mid-February to mid-May. However, the rainfall is characterized by inter-annual and inter-seasonal variations. This short rain period is of some agricultural importance, particularly in the north-east where annual rainfall is low. The “*Kiremt*” or main rainy season lasts from June to September (NBI, 2007).

The main production system in the basin is mixed crop-livestock production. In the highlands cropping is permanent whilst in the lowlands it incorporates bush fallowing and shifting cultivation. There is high sheet erosion in the basin due to the steep slope and the high rain fall especially around Mount Choke. The total soil eroded within the landscape is estimated to be 363.4 million tons/year and some 122.2 million tons of soil washes away from the cultivated land (NBI, 2007).

One of the sub watersheds of the Upper Blue Nile basin is the Gedeb watershed. It comprises of four districts namely Gozamn, Senan, Machakel and Debre Elias in the Amhara regional state which is 300 km away from Addis Ababa (the capital city of Ethiopia). The elevation of the Gedeb watershed ranges from 1,500 to 4,000 meter above sea level (MASL). The Gedeb watershed covers a total area of 871 km^2 with an estimated population of 495,439 according to CSA (2007). Agriculture is the main occupation for some 81 percent of the households with more than 96 percent of them owning livestock, the farming system can be characterized as mixed crop-livestock system on a subsistence basis. Major crop types in the area include *tef*[1] (*Eragrostis tef*) wheat, barley, potato and *Engedo*[2] *(Avena sativa).*

INSERT FIGURE 1 HERE

The Gezira Scheme (GS) is the other study site where the offsite costs of erosion is analyzed. The GS is located between the Blue and White Nile towards their confluence. It was established in 1925 when the Sennar Dam across the Blue Nile was completed. In 1959-63 the original

[1] *Tef* is the staple cereal in Ethiopia
[2] Local name for one of the barley variety

Gezira Scheme was extended to include the Managil area. The combined Gezira/Managil Scheme now covers a command area of about 882,000 hectares under gravity irrigation. Estimates of the total potential cultivable area under irrigation in Sudan within the Nile Basin vary, but it is probably between four and five million feddan depending, of course, on the availability of water. Hence the GS represents about a quarter of all irrigation area in Sudan and half the area of irrigation schemes drawing water from the Nile system (Plusquellec 1990). The Gezira scheme is considered as one of the most important scheme for food production in the country where 65 percent of the country's cotton production, 70 percent of wheat production, 32 percent of sorghum production, 15 percent of ground nut production and 20 percent of vegetable production comes from this scheme. In addition, 1.7 million of animal heads including cattle, camel sheep and goat are also produced in the scheme (Elfadua and Ahmed, 2008) (Figure 2).

INSERT FIGURE 2 HERE

Method

Cost Benefit Analysis (CBA) techniques provide a coherent framework for integrating information on the biophysical and economic environments faced by farmers. The basic principles of the analysis are straightforward. First, the effects of continued erosion (or other types of soil degradation) on productivity are estimated for the time horizon of interest. These are then used to estimate returns at each point in time. Second, the calculations are repeated under the conditions that would be experienced if a specific conservation measure were adopted (Lutz et al., 1994).

The returns to the investment in this measure are then obtained by taking the difference between the streams of discounted costs and benefits in the cases with and without conservation. This method estimates the returns to the specific conservation measures being examined, not to conservation per se (ibid). CBA is based on the principle of opportunity costs. Resources (e.g. land, labour, capital) invested in, for example, soil conservation, could also be invested in other enterprises. The value for these inputs is therefore assumed equal to the foregone benefit of investing these resources in an alternative enterprise. There are four common evaluation criteria used in comparing the costs and benefits of investment or alternative actions. These include the Net Present Value (NPV), Internal Rate of Return (IRR), the Benefit-Cost Ratio (BCR), and the Net Benefit-Investment rate (Gittinger, 1982). In this study the Net Present Value criteria is used to compare costs and benefits of soil conservation measures in the Gedeb watershed and the Upper Blue Nile basin.

Data

The data was collected on a face to face interview with 500 households who reported to have implemented soil conservation measures mainly soil bund, stone bund and fanya juu[3] on their plots of land in the past five years (2004-2008). The survey was conducted in the three woredas of the Gedeb watershed namely Gozamn, Machakel and Senan in July 2009 using random sampling technique. The data used for the estimation of onsite costs of soil conservation include labor, equipment and forgone crop production. The cost of labor for the three soil and water conservation measures was estimated using the current market price for labor in the respective areas. The forgone crop production is calculated based on the slope of the area, the steeper the

[3] these are widely used conservation measures in the area

slope the smaller the spacing between the bunds and the higher the percentage of area taken by the measures. The three locations are found at different slope gradients, Senan is between 15-50 percent slope gradient while, Gozamn and Machakel are between 8-15 percent slope gradient on average[4]. Crop loss is calculated based on the assumption[5] that in Senan the bunds take 15 percent of the area and in Machakel and Gozamn the bunds take 8 percent of the area on a per hectare basis. The cost of equipment is considered the amount of money spent on the purchase of shovel[6] which is used for the construction and maintenance of soil conservation measures as reported by farmers. It is noted that shovel is used for other farm activities as well, hence, only 50 percent of the cost is assumed as an equipment cost in the calculations. The costs of production include fertilizer, seed and land tax both for the with and without soil and water conservation situations. The onsite benefits from soil conservation measures included in the analysis are increased crop yield, straw and pasture (fodder) that grow on soil and fanya juu bunds.

The costs and benefits of soil conservation measures in the Upper Blue Nile basin and the avoided damage cost of sedimentation at the Gezira scheme in Sudan are calculated based on secondary information both from Ethiopia and Sudan. The data collected for the estimation of the costs and benefits of soil conservation measures in the Upper Blue Nile basin in Ethiopia include total agricultural worth of grain production, total cultivated land in hectare which is vulnerable to soil erosion and share of cultivated area which is subject to soil conservation. For

[4] Source of information is Senan woreda agricultural office
[5] This assumption is based on estimation of area loss due to conservation structure made by Shiferaw and Holden (2001).
[6] It is reported that shovel is the only instrument used for the construction of soil conservation measures in the study area.

the estimation of the damage cost at the Gezira irrigation scheme the data considered include total irrigated and rainfed area (area in hectare that is currently not irrigable because of siltation or shortage of water) occupied by cotton production, the per ton export price of cotton and the average per hectare yield from irrigated and rainfed cotton production and the dredging cost of sedimentation of the canals.

4. Result

Sample characteristics

A brief overview of sample characteristics in the three woredas will be presented followed by the discussion of the CBA estimation results. The survey respondents were mainly male headed households (90 %) with an average age of 46 and family size of 5. Their level of education varies from illiterate (42%) to those who can read and write without formal education (36%) and who had joined formal education (22%). These characteristics are quite similar across the three locations. Mixed farming characterizes respondents, they are involved both in crop production and animal rearing with varying average land size and livestock holding. The average land holding for Machakel is 1.2 hectare while it is 0.8 hectare for Gozamn and Senan. All farmers own livestock measured in TLU[7], these averages are 5.2, 5.0 and 3.3 for Machakel, Gozamn and Senan respectively. Farmers in Machakel earn the highest average annual income from crop production, (birr 11343) and the average is relatively lower for Senan (birr 7371) and Gozamn (birr 7788).

[7] Tropical Livestock Unit, where 1 TLU is equal to 250kg live weight of a cattle.

Soil bund, stone bund and fanya juu are the widely used soil conservation measures in the area. Soil bunds are used most often (68% of all the cases), followed by fanya juu (18%) and stone bunds (14%). Stone bunds are used least because of the lack of sufficient stones. Soil bunds are most common in Senan (79%) and Gozamn (70%), while fanya juu (27%) and soil bunds (55%) are most often applied in Machakel. Almost all of them know the advantage of soil conservation measures this was disclosed through the rating they gave for the evaluation question presented to them from very important (47.9%) to important (49.9%). Table 1 reports some of the household characteristics.

INSERT TABLE 1 HERE

Cost of soil conservation measures

The average per hectare cost of the three soil conservation measures is estimated considering the assumptions stated in the previous section. Accordingly, the aggregated average annual per hectare cost of implementing the measures in the three location is birr 1,030 while the average cost for each measure in all the locations being birr 1799/ha/year for fanya juu bund which is the highest and birr 758/ha/year for soil bund, relatively the lowest whereas the cost of stone bund is estimated to be 1327/ha/year. The comparison of costs across the three locations show that the implementation cost of soil bund (birr 658.87) and stone bund (birr 1261.07) in Gozamn are relatively lower than the other two locations. In Machakel fanya juu, is less costly with an average implementation cost of birr 1731/ha/year. In Senan all the measures are relatively expensive according to the estimation result. One reason could be the higher slope gradient of 20-50 percent which requires farmers to put more conservation structure with a smaller spacing between the structures which ultimately results in a higher cost. However, soil bund has a relatively low cost among the costs estimated and it is the type of measure recommended for the area of higher slope gradient. Table 2 reports the costs of the three measures.

INSERT TABLE 2 HERE

Discounted Net Gain (DNG)

The benefit from soil conservation accrues over time, hence, the net returns were discounted applying 12 percent[8] discount rate and net present value was computed over 10 year. The discounted net gain was calculated by subtracting the net present value of the project with soil conservation from the net present value of the project without soil conservation measures. Discounted net gain (loss) was estimated for soil bund, stone bund and fanya juu for the three woredas.

In Gozamn woreda the implementation of soil bund and fanya juu results in incremental net gain indicating the financial attractiveness of the measures in the area. The incremental net gain from soil bund is higher, (birr 500/ha) when compared to fanya juu, (birr 366/ha). This may be because the construction of soil bund is not as expensive as that of fanya juu which is found to be the most expensive among the lists of the conservation measures we estimated. The discounted net gain calculated for stone bund did not yield positive result which may suggest that stone bund is not a viable means of soil conservation measure in Gozamn.

[8] The minimum official borrowing rate in the Commercial Bank of Ethiopia currently is 8 per cent

The discounted net gain in Machakel is negative for all types of conservation measures. Farmers cannot benefit from increased yield by implementing conservation measures. One justification could be soil erosion is not causing severe damage in the area, hence, the investment and maintenance cost outweigh the avoided damage cost (benefit). On the other hand in Senan farmers can reduce soil erosion and benefit from the conservation if they implement soil bunds. The discounted net gain shows that farmers can get higher benefit of birr 1824/ha from crop production if they implement soil bund. According to the estimation result there is no economic rationale behind implementing stone bund and fanya juu in Senan as the discounted net gain is negative for these measures.

Sensitivity analysis was performed to test the sensitivity of input parameters and the reliability of the cost benefit analysis results. Higher and lower discount rates of 5-30 percent and increased labor cost of 10-30 percent were applied to investigate the changes that could be caused to the original result. A lower discount rate of 5 percent showed that discounted net gain from the implementation of both soil bund and fanya juu increased by 91 percent from the original result in Gozamn. On the contrary, a higher discount rate of 20-30 percent reduced the net gain by 50-78 percent from the original result. In Senan a lower discount rate of 5 percent improved the discounted net gain by more than 90 percent, when the discount rate is increased the net gain dropped by 50-60 percent from the original result. This indicates that higher time preference decreases the benefit of the future while less time preference will help to keep the resource for the future generation. In Machakel the discounted net gain changed for both lower and higher discount rate and approached positive values even though none of the measures discounted net gain turned positive.

The second type of sensitivity analysis conducted was by varying the labor cost from 10-30 percent both for the with and without soil conservation scenarios. However results indicated that labor cost was not found to be sensitive to cause any significant change on the cost benefit analysis estimate. In all the cases there was insignificant (less than 10 percent) change in the discounted net gain due to the variation in labor cost. Table 3 presents the estimates of the discounted net gain for all the measures across the three locations and the result of the sensitivity analysis for the lower and higher discount rates.

INSERT TABLE 3 HERE

Onsite costs and benefits: the upper Blue Nile basin

In the previous section the per hectare average cost of soil conservation measures is calculated for the Gedeb watershed and the aggregated cost for the three measures on average was found to be US$ 79[9] /ha/year. In the estimation of the costs of the measures for the upper Blue Nile basin as a whole, adjustment is made on the shadow wage rate. Following Araya and Adjaye (1999), the economic price or the opportunity cost of labor is calculated by assuming the mean number of days farmers spend in on-farm employment to be equal to 99 and the total number of days in the off-peak season to be 180, calculating the ratio provides a factor of 0.55. Applying this factor to the market wage rate gives a shadow wage rate of US$ 1/day. Hence, the average cost of the measure for the adjusted labor price is estimated to be US$ 39/ha/year. Multiplying this average

[9] In this section and in the coming sections the costs and benefits are estimated using USD in order to make comparison with the offsite cost easier. One USD is equivalent to 13 Ethiopian Birr (CBE, 2010).

cost by the area of cultivated land which is vulnerable to soil erosion in the basin, 1.08 million[10] hectare yields a total cost of US$ 42.12 million/year. Since the cost is of an investment nature it has to be spread throughout the years and discounted. Therefore, to estimate the cost of soil conservation applying a social discount rate of 8 percent and a time horizon of 20 years, the annual accumulation amount after 20 years gives US$ 842.24 million and discounting provides a total cost of US$ 180.73 million.

In the estimation of the onsite benefit of soil conservation measures, the cost of erosion is used as a proxy to measure the benefit. Some studies estimated the total cost/ha/year of soil erosion from wheat production in Ethiopia to be US$ 544 in high soil loss areas[11]. When we translate this estimate to the total area vulnerable and subject to soil conservation measures in the upper Blue Nile basin which is approximately equal to 5.43 million hectare, we arrive at a total cost of US$ 2.9 billion per year. If we assume 20 years of planning horizon, this annual amount accumulates and after 20 years a cumulative total of 20 years' worth of erosion will have been prevented, which will in that year yield US$ 59.1 billion in onsite benefits. Discounting this using a social discount rate of 8 percent provides a present value of US$ 12.7 billion which is equivalent to the onsite benefit of an effective soil erosion control program in the upper Blue Nile basin.

Offsite costs: the Gezira irrigation scheme

For the estimation of the damage cost of sedimentation at the Gezira irrigation scheme the loss from cotton production is considered since cotton production has the biggest share in the Gezira

[10] NBI(2007)
[11] Sertsu (1999)

irrigation scheme with approximately 80 per cent of the exported extra long-staple cotton and 40 per cent of the exported medium-staple cotton are produced by the scheme. The total revenues from export of both long-staple and medium-staple cotton averaged US$208 million from 1978 to 1988, with an average annual growth rate of 4.5 per cent[12]. However, unstable total area and production are of high concern at the national level on account of their effect on export earnings and government budget (Faki, 2006). The area covered by cotton production decreased from 240,000 ha in the 1970s to 60,000 ha in 2000/2001 because of shortage of irrigation water due to sedimentation of the irrigation canals (Elfadul and Ahmed, 2008).

To estimate the loss from cotton production due to shortage of irrigation water at the Gezira irrigation scheme, comparison was made between production with and without irrigation. According to the information provided above 180,000 hectare of land is no more irrigable due to shortage of irrigation water, hence cotton is produced on this land under rainfed agriculture only. The average rainfed cotton production is estimated to be 0.44 ton/ha/year while this average is 1.42 ton/ha/year in the case of irrigated agriculture[13]. If this 180,000 ha was under irrigated agriculture the average production would have been 255,600 ton/year, however, currently only 79, 299 ton/year is being produced with rainfed agriculture which reduced the cotton yield by 176, 400 ton/year, this is the average annual amount of cotton production lost due to shortage of irrigation water. When we multiply this with a per ton export price of US$ 1000 the loss will be US$176.4 million/year. The accumulation of this annual amount over 20 years provides US$ 3.5 billion, a social discount rate of the same 8 percent gives the present value of a total loss of US$ 756.9 million

[12] Bank of Sudan annual reports.
[13] Faki (2006).

On the other hand the cost of removing sedimentation from the canals of the Gezira irrigation scheme as estimated by the Ministry of Irrigation in Sudan ranges from US$ 4.5 million in the 1980s to US$ 28 million at the end of 1990s. The estimated quantity of sediment in the canals increased from 5 million m^3 in the 1980s to 40 million m^3 at the end of the 1990s. In 2009 the estimated dredging cost is reduced to US$ 12.5 million though the sediment showed increase from the 2008[14]. If we assume the dredging cost of 2003 as an average cost, which is US$ 22.5 million and work out the same calculation for 20 years we arrive at US$ 450 million, discounting with 8 percent gives a present value of US$ 96.5 million. The income loss due to water shortage and the dredging cost of canals give the present value of an aggregated offsite cost of US$853.4 million.

From this estimation result we can observe that the cost of conservation at the upper Blue Nile basin is less than (US$ 180 million) the offsite damage cost at the Gezira irrigation scheme (US$ 853.4 million). Moreover, the onsite benefit from effective soil erosion control program is large enough to convince policy makers that conservation measures in this part of the country are beneficial both to the society within the country and to the people downstream of the basin.

5. Conclusion and recommendation

Despite long standing concern about the threat of land degradation and continued effort to curb the problem through the implementation of soil conservation measures, many of the conservation programs designed to address the problem have fallen short of expectations. Often farmers have

[14] Abedalla (2009).

not adopted the recommended conservation practices or have abandoned them once the project is ended. This study estimated the costs and benefits of these measures both at the household and the watershed level, the associated off-site impacts are also addressed to some extent though lack and inconsistency of data are found to be the main limitations of the study.

The success of soil conservation measures depend on a number of factors among others, agroecology, slope gradient, ownership or titling to land, mode of participation (voluntary or mandatory) of the target group and perception of erosion problem are paramount important. Soil and water conservation measures take significant portion of crop land and higher investment cost especially in the first year, hence, benefit of these measures may not be realized immediately and this discourage farmers to commit themselves to implement these measures and maintain regularly. In order to compensate the area of land farmers' lose due to the structures, additional income generating activities such as planting of fodder and trees on the bunds can be one solution.

The cost benefit analysis conducted in the three woredas disclosed that soil and fanya juu bunds are financially attractive conservation measures in Gozamn and Senan woredas. In Machakle none of the measures give positive net present value suggesting that soil erosion is not a major problem in this area, hence, the implementation of measures in an area where the problem is not significant results in higher cost than benefit. The estimation of benefit at the watershed level indicated that the upstream benefits are sufficiently large to justify soil and water conservation measures. Similarly, the comparison made between the offsite damage cost at the Gezira irrigation scheme and the onsite cost of erosion control measures in the upper Blue Nile basin suggests that the damage costs at the Gezira irrigation scheme is greater than the cost of erosion control measures in the upper Blue Nile basin.

The study suggests that a government policy that takes in to account the above mentioned factors that determine the success of soil conservation measures can help achieve the objectives of conservation. In addition, the offsite damage cost can be reduced through a coordinated effort between the governments of the two riparian countries (Ethiopia and Sudan) since the conservation cost in the upstream of the basin is significantly lower than the damage cost at the Gezira irrigation scheme.

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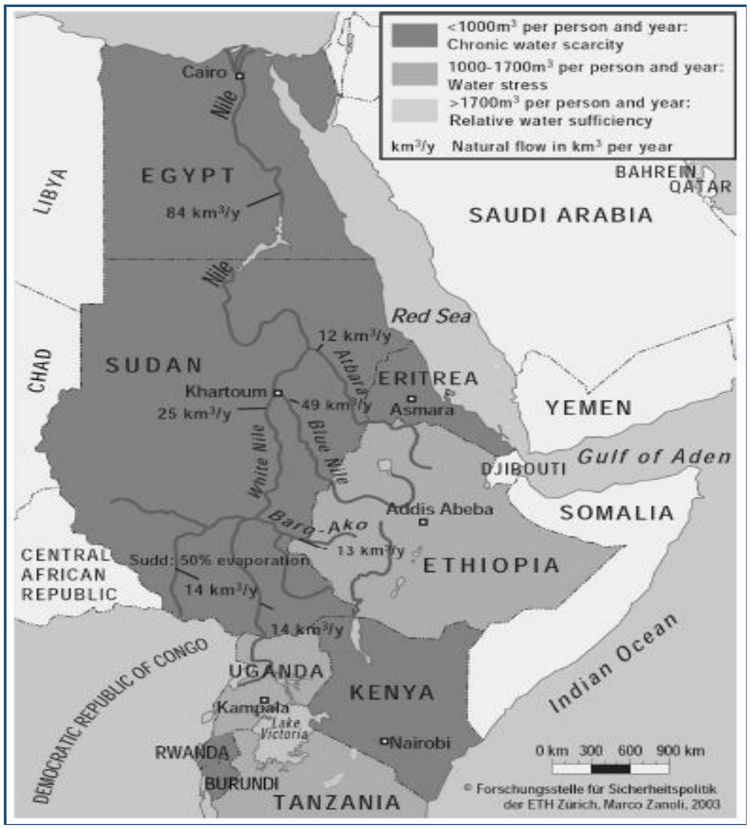

Fig. 1. the Blue Nile river basin
Source: (Timmerman, 2005; NBI, 2006)

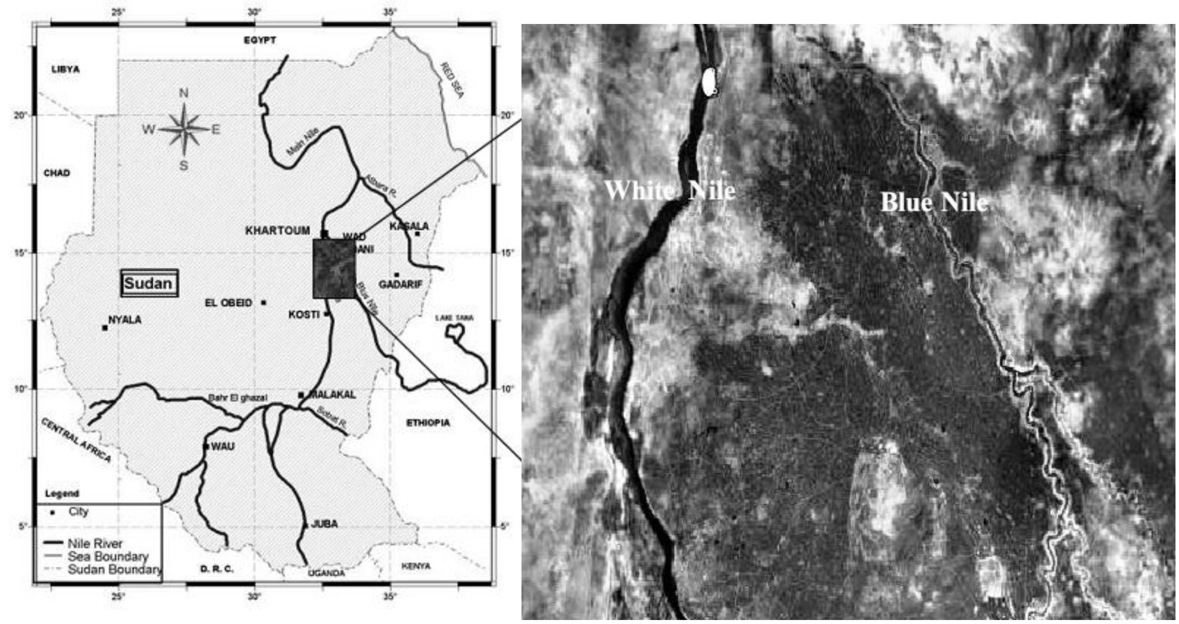

Fig. 2 the Gezira irrigation scheme
Source: (MoI, 2009)

Table 1 Sample characteristics of respondents

Household characteristic	**Machakel**	**Gozamn**	**Senan**
Gender (% male)	83	97	96
Average age	49	44	45
Share illiterate (%)	37.3	44.3	45.9
Average household size	5.3	5.8	5.6
Average land size (ha)	1.2	0.8	0.8
Average livestock holding (TLU)	5.2	5.0	3.3
Average income from crop production (Birr/year)	11343.8	7788.6	7371.0
Average income from off-farm activity (Birr/year)	1434.7	1339.2	1477.1
Importance of conservation measure (% very imp)	49.4	52.7	41.0
Importance of conservation measure (% important)	49.4	45.6	55.1
Share type of measure implemented (% soil bund)	55.7	70.4	79.0
Share type of measure implemented (% fanya juu bund)	27.0	17.2	11.5
Share type of measure implemented (% stone bund)	17.2	12.4	9.6

Source: own computation

Table 2 Average annual cost in birr for soil conservation measures in the Gedeb watershed

Location	Average cost of measures in birr/ha/year			Total cost of measure
	Soil bund	Stone bund	*Fanya juu*	
Gozamn	658.87	1261.07	1813.91	931.90
Machakel	940.99	1331.18	1731.00	1221.66
Senan	712.01	1411.31	1953.40	921.15
Total	758.74	1327.08	1799.16	1029.36

Source: own computation

Table 3 Discounted Net Gain (loss) from soil conservation practice (in 1000 birr/ha)

Discount rate	Gozamn			Machakel			Senan		
	Stone bund	Soil bund	Fanya juu	Stone bund	Soil bund	Fanya juu	Stone bund	Soil bund	Fanya juu
0.05	-3.603	0.952	0.699	-0.201	-0.008	-0.503	-0.632	3.478	-0.766
0.12	-1.889	0.499	0.366	-0.105	-0.041	-0.263	-0.331	1.824	-0.402
0.20	-0.947	0.250	0.183	-0.052	-0.002	-0.132	-0.166	0.915	-0.201
0.25	-0.630	0.166	0.122	-0.035	-0.001	-0.087	-0.110	0.608	-0.134
0.30	-0.425	0.112	0.082	-0.023	-0.001	-0.059	-0.074	0.411	-0.090

Source: own computation