Financial Efficiency and Intergenerational Equity of Soil and Water Conservation Measures in Kenya

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Research Article

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ABSTRACT

The present study, conducted in Upper Tana, Kenya, has the objective of assessing viability and profitability of structural and non-structural soil and water conservation measures among smallholder farmers. Financial cost benefit analysis (FCBA) framework was used to analyse primary data collected from 433 smallholder farmers in Upper Tana. Similarly, a review of methodological experiences and challenges in assessing benefits accruing from conservation measures to future generations was also conducted. Structural and non-structural conservation measures studied were financially attractive with bench terraces and Napier grass strips attaining higher net present values than other structural and non-structural measures studied respectively. The gross margins of the conservation measures were also positive in the year of study. Labour and materials were the major inputs required for establishing and maintaining conservation measures. However, farmers needed a conducive institutional framework and land use policies, technical advice and support, favourable input-output market and credit to invest on conservation measures on a sustainable basis. Analysis at 15, 30, 60 and 90 year time horizons and at different discount rates (10%, 12% and 14%) using FCBA indicated that the higher the discount rate, the less were the streams of benefits. Similarly, a longer period of analysis at a constant discount rate resulted in marginal benefits bringing into question the application of conventional FCBA to intergenerational equity assessments and whether it is appropriate to conduct analyses at 60 and 90 year time horizons using FCBA. Reviews of methodologies for assessing conservation benefits to future generations indicated divided opinions on use of discount rates and methodologies.

Keywords: Soil erosion, Cost and Benefits, Equity, Smallholders, Land management options, Soil conservation.

INTRODUCTION

One of the critical resources for livelihoods for this generation and the generations to come is land. Over time, humans have exploited land resources in an unsustainable way and land degradation has become a global problem (Eswaran et al., 2001). Human induced land degradation is the reduction or loss of the biological or economic productivity of the land attributed to a combination of processes such as soil erosion and deterioration of the physical, chemical and biological properties of the soil and loss of vegetation (Evans and Geerken, 2004). Land degradation not only threatens the livelihoods of the present generation, but also of the next one. It is estimated that land degradation due to water and wind erosion, respectively account for 46% and 38% of total soil degradation in Africa (Sivakumar and Wills, 1995). Land degradation includes the loss of productivity of the soils-top layer (mineral and organic materials) of the earth that serves as a natural medium for the growth of plants.

Structural and non-structural (agronomic and vegetative) soil and water conservation measures have been proposed to address land degradation due to water and wind and to reverse productivity losses (Nyssen et al., 2009; (WOCAT, 2007)). The benefit that a farmer receives from land conservation is derived from the fact that soil is a potential income yield asset (Pagliola, 1994). The ‘stock’ of soil available to a farmer is essentially an economic asset that can be exploited through cultivation to yield a stream of present and future income (Hacisalihoglu et al., 2010). However, implementation of soil and water conservation measures can be costly, either directly in terms of investment requirements or indirectly in forgone production. Such costly investments often decrease immediate benefits and have long gestation periods.

Farmer’s decision to invest in conserving the land depends on the costs to be incurred relative to the value of output or environmental benefits expected. Since the value of fertile soil is not infinite relative to other human needs, it is not worth preventing soil degradation unless the benefits gained exceed the costs incurred in conservation activities (Barbier and Bishop, 1995). Many environmental economists agree that price tags can be
assigned to the “environment and natural resources and associated goods and services” to avoid their degradation, overuse and abuse and to encourage their conservation. This is further supported by Agenda 21 on the Chapter on integrating the environment and development (Section 8.2; Section 8.41) which proposes that the environment and natural resources can be valued the same way as we value human-made assets (UN, 1992). Methods such as contingent valuation (willingness-to-pay or stated preference methods), hedonic pricing, and travel cost methods among others, have been devised to assess the monetary value of non-traded environmental goods and services while Cost Benefit Analysis (CBA) has been traditionally used in environmental and natural resource management to determine efficient use and conservation and to integrate environmental costs into development decisions (Arrow et al., 1993; Price, 2000).

CBA and the application of financial investment analysis procedures (net present value and discount rates, internal rate of return etc.) have been proposed to answer the question as to whether an investment in soil and water conservation measure pays-off, over a given time horizon under the assumption that farmers experience improved yields and other environmental benefits as a result of implementing conservation measures (Bojö, 1991). CBA puts all relevant costs and benefits on a common temporal footing by converting the future expected streams of costs and benefits into a present value amount using a discount rate. The use of CBA to assess streams of costs and benefits arising from implementation of soil and water conservation practices within the time scale of the present generation and to ensure intergeneration equity is a debate in the public domain with various divergent views (Portney and Weyant, 1999). Intergenerational equity refers to balancing the needs of the present generation with future generation regarding costs and benefits that accrue from implementation of development interventions and in this case soil and water conservation options; while equity is a concept of social justice and implies fairness, and that there should be a minimum level of income and environmental quality below which nobody falls (Beder, 2000).

To date, the financial efficiency and intergenerational equity for soil and water conservation measures in Kenya are ignored (Atampugre, 2011; Ellis-Jones and Tengberg, 2000).

Intergenerational equity is central to the definition of sustainable development. Sustainable development has been defined as “development which meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987). Therefore, balancing the needs of future generations with the present requires that natural resources be used in such a way that future generations can still have the ability to create wealth as we have (Barbier, 2003).

Attempts to assess distribution of benefits between generations from development interventions such as conservation practices are characterised by methodological challenges. Questions have been raised on the use of discount rates, definitions of a “generation” and the suitability of approaches used in assessments (Pan and Kao, 2009; Padilla, 2002). To assess intra-generational and inter-generational equity, the definition of a generation needs to be made explicit. A generation is the period of time between the birth of parents and children, a time span of 20-30 years (Young, 1995; Oxford-English-Dictionary, 2008; Verrelli et al., 2002). However, other authors have argued that a generation, average of 30 years, is too long a span of time to assess intergenerational equity for global environmental critical issues and a shorter time span, say 20 years, would be appropriate (Pan and Kao, 2009). While there is some convergence in opinions on the use of social discount rates to assess the stream of benefits accruing to the present generation (time spans of up to 40 years) when a development intervention is implemented, opinions are divided on its use in intergenerational equity assessments for development interventions whose environmental effects are long-term (Sáeza and Requena, 2007). Some authors have adduced evidence and models that indicate that social discount rate can be used the same way irrespective of whether one is conducting intergenerational equity assessment or intra-generational equity assessment while others propose variations of discount rates or completely new approaches (Toth, 2000).

To address the above issues, this study had two objectives: (i) to assess viability and profitability of structural and non-structural soil and water conservation practices implemented by smallholder farmers and (ii) to review methodological experiences and challenges of assessing benefits from conservation practices over a time horizon that spans more than one generation (intergenerational equity). The paper also presents limitations and major conclusions emerging from the study.

**MATERIALS AND METHODS**

**The Study Area**

The study was conducted in Upper Tana catchment, covering parts of Central and Eastern Kenya (Figure 1). The Upper Tana covers an area of 17, 420 km², has a population of 5.2 million people and include 24 river basins (sub-catchments), three of which are included in this study. The population density of Upper Tana is high and is estimated at an average of 300 inhabitants per km² (IFAD, 2012). The area experiences a bimodal rainfall pattern that follows an elevation gradient with annual rainfall of less than 700 mm at altitudes below 1000 meters above sea level, 1000 to 1800 mm at mid elevations (1200 to 1800 metres above sea level) and as high as 2500 mm annual rainfall at higher altitudes of 1859-3000 metres above sea level (Otieno and Maangi, 2000). The dominant
soils are volcanic ash soils (Andosols) at higher elevations (Mt. Kenya and the Aberdares), deep well structured, nutrient rich clay soils (Nitisols) at middle foot slopes, very deep strongly leached poor clay soils (Ferralsols and Acrisols) and less leached soils (Cambisols, Regosols, Lixisols and Luvisols) at lower foot slopes among other soil types (Sombroek et al., 1983).

Although the Upper Tana is an important agricultural region, it is in the same region where a cross-section of the very poor and less poor communities also live. Poverty in the area has a spatial distribution with lowest poverty levels at high altitude areas and along river basins (35% of the population live below poverty line), (WRI, 2007). The communities in the lower plains and in the drier parts of the region have high poverty levels with more than 55% of the population below poverty line. High levels of rural poverty persist because of the high population growth rate, small landholdings, large rural income disparities and strong linkages between poverty and environmental degradation, soil erosion and declining soil fertility (IFAD, 2012).

Mixed farming, involving crop production and raising of livestock, is practiced in Upper Tana. There is intensive rain-fed farming in the upper reaches of the catchment. Rainfed farming is done in two rainfall seasons: Long rains (March to June) and Short rains (October to December). The cash crops grown include tea, coffee and fruit trees like mangoes, macadamia and avocado. Other crops include bananas, maize, beans, sweet potatoes and vegetables (kales, spinach and green peas). The farmers in the drier parts of the catchment (Cotton-tobacco zone) grow tobacco and sunflower as cash crops and also subsistence crops like maize, sorghum, pigeon peas, green grams, Dolichos lablab and cassava. Small scale irrigation is practiced to some extent in the catchment with the following crops being grown: tomatoes, cabbages, onions, sweet pepper and kales among others. Common livestock kept in the study area include cattle, goats, sheep and poultry. A few households keep pigs and rabbits. Manure from livestock is used in the farms while livestock also benefits from feed (mainly Napier and grass) grown in conserved lands.
Dominant soil and water conservation practices in the study area include *Fanya juu*, grass strips, bench terraces, retention ditches, planting trees, banana micro-catchment and cutoff drains. Others include ridging, contour tillage, riverine protection, trash-lines, stone lines, cover crop, zero tillage and *zai* pits among others. The use of stonelines is dominant in the drier parts of the sub-catchments. Inputs for establishing soil and water conservation practices (structural and non-structural measures) include labour; implements (*fork jembe, panga*, hoe, spade, axe, wheel barrow, mattock, pruning knife, file, leveling board and spirit level); materials (Napier grass-*Pennisetum purpureum*, trash materials, mulch materials, stones, stabilizer planting materials-seeds, seedlings cuttings; herbicides) and other materials such as strings and pegs.

Farmers in the study area, though dependent on family labour for establishing and maintaining soil and water conservation practices, use various strategies to address labour shortages. The strategies include labour work parties, hiring casual labour in times of need, seeking support from relatives in peak periods, hiring permanent/resident labour, using hired traction (animal draft power; tractor), implementing practices in small portions of the field each season until the whole farm is covered and planting high value crops with returns expected to offset initial labour costs (*ibid*).

**Farm Household Selection and Sample Size**

The study households were selected from three sub-catchments of Upper Tana, namely Lower Chania, Kayahwe and Tungu. The sub-catchments were purposefully selected for this study to include areas where soil erosion and land degradation were considered to be high and areas covered by a sub-catchment management plan under a water resource users association (WRUA). The sub-catchments were stratified into three; upper, middle and lower elevation zones as defined in sub-catchment management plans, with each sub-catchment spreading across four to five agro-ecological zones. Depending on the sub-catchment, the upper elevation zones were tea-dairy zone and or tea-coffee ecological zone. The middle zones were main coffee zone while the lower zones were either marginal coffee zones or cotton-tobacco zones. The descriptions of agro-ecological zones including the use of terminologies such as highlands, midlands and lowlands have been detailed by (Jaetzold et al., 2006). Each zone was further delineated into smaller “area grid units”. Farm households that had undertaken the same soil and water conservation (SWC) practices were sampled from each area grid unit, ensuring that each part of the zone is covered by the study. Farmers selected were representative of the zone from where they were selected from. Since one of the objectives of the study was to assess the viability of the soil and water conservation practices based on on-farm costs, it was considered relevant to gather data and information from farmers who have adopted those specific practices. A total of 433 households were selected for the study spread across the three selected sub-catchments.

**Soil and Water Conservation Practices studied**

Soil and Water conservation practices studied were selected in collaboration with various stakeholders taking into account the existing knowledge on Upper Tana, farmers practices, agro-ecological zone where such practices are found and perceived potentials and limitations of such practices. The SWC practices selected comprised structural and non-structural measures. Structural measures were defined as permanent features formed from earth, stone or masonry that are designed to protect the land from uncontrolled run-off, encourage infiltration into the soil and retain water where needed (Thomas et al., 1997; WOCAT, 2007). Nonstructural measures were defined as vegetative and agronomic measures that promote soil and water conservation through reduced run-off, encouraging infiltration and moisture retention, and reducing evaporation to the atmosphere. The following structural measures were studied and are described below (Thomas et al., 1997):

- **Bench terraces**: Bench terraces are level or nearly level steps constructed on the contour and separated by embankments known as *risers* with the purpose of reducing the slope of cultivated land, reducing surface run-off and increasing infiltration of water into the soil.
- **Fanya juu**: A *fanya juu* terrace is made by digging a trench and throwing the soil uphill to form an embankment that impounds water, soil and nutrients; a storage area above the embankment to prevent over-stopping by run-off and a berm/sledge to prevent the embankment soil from sliding back into the trench.
- **Cut-off drains**: Cut-off drains (or diversion ditches) are graded channels with a supporting ridge or bank, on the lower side constructed a cross or a slope to intercept surface run-off and convey it safely to an outlet such as a waterway.
- **Infiltration (retention) ditches**: Infiltration ditches are designed to catch and retain all incoming run-off and hold it until it infiltrates into the ground. They are constructed at zero gradient (not graded) with closed ends, wide and deep enough to hold expected run-off.
- **Contour stone lines**: Contour stone line consists of a single line of stones on the contour.
Except for stone lines, structural measures reported in this study were stabilised by grasses on terrace embankments or risers. The descriptions of non-structural (agronomic and vegetative) measures studied are given below (Thomas et al., 1997):

- **Trash lines**: Trash-lines are constructed by laying plant residues or trash in lines along the contour. The trash-lines in the study area did not have pegs on the lower side to prevent the trash being washed away.
- **Grass strips**: A grass strip is a narrow band of grass planted on cropland along the contour. The grass strips studied were mainly of Napier grass (*Pennisetum purpureum*) fodder, although different grasses can be grown on the band.
- **Contour planting + tillage**: The practice of contour tillage and planting (contour farming) studied involves cultivation, planting and weeding along the contour “without making furrows and ridges”.
- **Contour ridging**: Contour ridging practices studied involves making small furrows and ridges across slopes during cultivation and or weeding with crops being earthed up. The spaces between the ridges form depressions or furrows in which rainwater collects and infiltrates into the soil. The contour ridges prevent run-off from small storms but can break during heavy storms unless cross-ties are made in the furrows.

### Data and Data Collection

**Data collected**

Primary data were collected from 433 households using a semi-structured questionnaire. Data were collected on household characteristics and resource endowments, farming system characteristics, qualitative perceptions on benefits of conservation measures, strategies for addressing labour requirements, and investment and maintenance costs of selected soil and water conservation practices as well as their benefits. Furthermore, local experts on soil and water conservation such as agricultural extension officers and “community markers” were interviewed to ascertain and triangulate information collected at farm level. Secondary data were collected on estimates of productivity loss due to erosion from experimental and survey studies for conditions similar to this study and from local market centres for relevant traded inputs and outputs. Similarly, secondary data on bank interest rates were collected and used as estimates of discount rates in this analysis. Secondary data were obtained from published studies and from discussions held with various experts on productivity loss due to soil erosion.

**Quantification and valuation of Investment and maintenance costs**

Input costs for SWC were classified, quantified and valued as investment (or establishment) costs and as maintenance costs (annual costs). Investment costs are incurred by a farmer when establishing SWC practice, expecting to realise benefits, though in the long-term. All costs that a farmer incurs when implementing SWC for the first time i.e. in the base year (year 0) were regarded as establishment costs (Stocking and Abel, 1992). Costs thereafter were regarded as annual or maintenance costs.

Investment and maintenance costs quantified for structural measures included labour, materials and tools and equipment. Investment costs considered in this study comprised three cost centres (i) costs that farmers incurred when laying out the SWC structure on the contour (lay-out costs) (ii) costs of establishing the SWC structures; and (iii) costs of establishing grass stabilisers on terrace risers/embankments. Maintenance costs for structural measures were considered to include costs associated with (i) structure itself and (ii) costs of maintaining stabiliser grasses on structure risers and/or embankments.

Non-structural measures such as contour tillage and planting (contour farming) and contour ridging are made every planting season; thus were considered to have variable costs rather than long-term investment costs. However, trash-lines and Napier grass strips studied have costs associated with establishment (lay-out costs and costs of establishing Napier grass strips).

Labour demand (person days) for constructing and maintaining SWC measures was obtained by asking the farmer for a given length of SWC structure. The responses were triangulated by interviews of organisations and community markers working in the Upper Tana to get an idea of labour quantity and costs according to “work standard ethics”. Aspects of labour investigated depended on the SWC structure in question but included the following:

- Labour for laying out the structures and pegging them along the contour
- Labour for excavation of trenches for structural measures
- Labour for applying trash lines and stone lines
- Labour for planting stabilizer grasses, grass strips and for carrying out tillage and ridging operations (land preparation, planting, fertilization etc.).
- Labour for maintenance of structures (repairs/cleaning trenches; gapping; fertilization; weeding; application of mulch and trash etc.).
Farmers own labour was valued at opportunity cost since farm-labour market exists in the study area. Hired labour was valued at farm-gate rates as given by the farmer. This was in the range of Ksh 150-200 (US $ 1.7 to 2.3) per Labour Day’s work, all inclusive. The cost of laying out structures was calculated based on opportunity cost since it is the Ministry of Agriculture and or Community Markers trained by Non-Governmental Organisations (NGOs) that lay out the structural measures and peg them out upon farmers request but at no direct cash cost.

Equipment and materials are investment and maintenance items that farmers require for implementing SWC measures. Tools and equipment include jembe, spade, panga and mattock (pick-axe). In this study it was assumed that labour costs also includes cost of tools since most hired labour do come with their own tools for farm work and are paid in lump sum for work done and not separately for their own tools that they have used. However, farmers own tools were included in the analysis as a form of contingency. The tools were valued at market prices or at opportunity costs where not traded. Non-traded materials such as stones (for stone lines) were valued at opportunity costs.

**Quantification and valuation of benefits from SWC structures**

The benefits of structural SWC measures, on retention of soil, nutrient and water, were identified as an increase in yields of grasses planted on the terrace risers and/or embankments and the crops planted in the terrace (conserved land). The crop yields comprised maize and bean grains as well as residues/stovers obtained after grain harvest as well as harvested yields of stabilizer grasses on structure risers and embankments. The study focused on maize and beans since they are grown across all the sub-catchments and ecological zones studied. The annual yields of grains and stovers and grasses were obtained from the farmers interviewed. The inputs for growing maize and beans were also identified, quantified and valued either at market prices where traded or at opportunity costs where not traded. Outputs (harvests of grasses, maize and beans) were valued at local market rates, where the products are traded and or at farmer’s best estimations where markets are non-existent for particular commodities. Both main products (such as grains, grasses) and by-products (e.g. stovers) were quantified. The inputs and other factors of production were valued at their observed farm-gate prices and/or at market rates while the farm household’s own, non-purchased resources were valued at opportunity costs.

In the study, it was assumed that land productivity is not entirely lost when structural SWC measures are implemented in the study area because SWC structures are a form of insurance facilitating crop diversification and providing a form of security to farmers in terms of stable yields, also farmers do plant fodder grasses and sweet potato vines on terrace risers and embankments as well as crops such as bananas in the trench itself. However, in the base year of SWC structure establishment, there will be no substantial yields and therefore, the yields are assumed zero (“or lost”). It was further assumed that farmers estimated yields of crops grown in the terrace takes care of the “would have been perceived negative effects” of Napier grass crops planted close by since farmers give actual yields when crops are grown close to Napier grass (Thomas et al., 1997).

**Estimating productivity loss due to erosion**

Erosion results in loss of productivity and net profitability of the farm through decreased crop yields and lost revenues. The beneficial effects of SWC are to reverse this situation. Change in productivity approach was used to estimate the net benefit of SWC measures by calculating the difference between costs, yields and revenues when erosion is taking place (“without SWC measure”) and when erosion is not taking place (“with SWC situation”). In this approach, the effects of erosion damage is calculated as the value of lost crop production valued at market prices (change in productivity approach)-i.e. the difference in crop yields with and without erosion, multiplied by the unit price of the crop, and less the costs of production (Grohs, 1994; Pimentel et al., 1995; Barbier and Bishop, 1995).

The change in productivity approach assumes that we observe farms with erosion (without SWC measure). However, we do not know what land productivity and income would have been in the absence of erosion (with SWC measure) on the same farm. This can be measured in experiments set up to determine costs, yields and revenues in farms where erosion is taking place (without SWC measure) and to do the same, over time, after SWC measure has been installed in the same farms (with SWC situation), a costly venture. Alternatively, studies comparing farms with SWC measure (“with situation”) and those without SWC measure (“without situation”) can be undertaken at either a single point in time or over time on the assumption that the two types of farms exist in the same farming system, agro-ecological zone or are near each other and therefore are faced with similar conditions- in reality the approach remains a challenge.

The yield of crops lost in the “without situation” were assumed to be a percentage of the yields obtained when SWC structures have been implemented in line with experimental data available and other on-farm studies. For structural measures (Bench terraces, fanya juu, cut-off drains, retention ditches and stone lines), maize yields in situations without SWC measure were assumed to be 50% low in the base year (Okoba, 2005; De Graaf, 1996; World-Bank, 1990; Atampugre, 2011). For non-structural measures (trash lines, grass strips, contour tillage, ridging), it was assumed that maize and bean yields were low by 14% in farms without SWC structures at
the base year (Tenge et al., 2005). It was further assumed that yields of crops in farms without erosion (with SWC measures) were stable and remain constant over the period of analysis while crop yields declined linearly over time by a percentage of the previous year’s yields in farms with erosion (without SWC measures) (Bojó, 1991). Yields of maize and other grain crops were assumed to decline linearly over time by a percentage of the previous year’s yields in farms with erosion (without SWC measures) (Bojó, 1991). Yields of beans were assumed to decline by 2% annually based on limited studies available (FAO, 1986; De Graaf, 1996; Atampugre, 2011). The decline in yields for beans was assumed to be equal to that of maize due to limited availability of experimental data.

**Profitability and Viability of SWC Measures**

Profitability and viability of the structural and non-structural measures of SWC were assessed using Cost Benefit Analysis (CBA) framework. Two types of analyses were carried out (i) profitability analysis of SWC measures in the year of study; and (ii) financial efficiency and viability of the SWC measures based on streams of costs and benefits over time. Profitability of conservation measures in the year of study were determined based on the following financial indicators:

(i) Gross margins (gross profit margin or gross profit rate), GM: Gross margin for each conservation practice was defined as the difference between gross revenues and total variable costs. In gross margin analysis, sunk costs such as establishment costs and tools and equipment not specific to one enterprise are normally excluded and the focus is given on variable costs. However, annuity of establishment costs for structural measures was included in profitability analysis; in this case to enable comparison with non-structural measures, some of which have no long-term investment costs. Conservation measures with positive gross margins are desirable and were considered viable.

(ii) Benefit cost ratio (undiscounted), BCR-undiscounted: The undiscounted BCR was calculated as gross revenues (benefits) divided by total variable costs. Positive undiscounted BCR greater than 1 is desirable.

(iii) Gross margins/Labour day: The gross margins divided by total labour days were used to estimate returns to labour. A positive value equal to or higher than the opportunity cost of labour is desirable.

The CBA framework was used to compare costs and benefits for implementing SWC and the extra income arising from conservation, on a year by year basis over a selected time period (time horizon) since the stream of benefits of conservation measures are realised in the long-term. The analysis was done for all conservation measures studied at a time horizon of 15 years based on the perceived life span given by farmers before re-investing in conservation measures again. This was compared with analysis at 30 year time span representing a time scale of one generation. For structural measures, further analysis was carried out at 60 and 90 year time spans to estimate benefits for “next generation”. Future benefits of the conservation measures were expressed in present value terms using social discount rates reflecting interest rates farmers pay when borrowing money from banks in the study site (Francisco, 1998). Interest rates charged by financial institutions ranged from 9-14% at the time of study. Three interest rates, 10%, 12% and 14%, were used in the analysis to capture diversity of interest rates farmers pay on loans borrowed, differences in time preference among farmers, challenges of using a specific interest rate for each farmer and to aid comparison and sensitivity analysis. Two decision criteria derived from CBA framework were used to illustrate the viability of SWC measures, namely:

(i) Net Present Value (NPV): Was defined as the current value of all net benefits of each conservation measure. Net benefits were calculated as the benefits minus the sum of costs. The stream of net benefits over time horizon of calculation (accumulated net benefits-NPV) was converted to present value using social discount rate. NPV was defined as:

\[
NPV = \sum_{t=1}^{T} \left( \frac{Benefit_t - Cost_t}{(1+r)^t} \right)
\]

Where

Net benefits at time \( t = Benefit_t - Cost_t \)

\( r \) = the discount rate

If the SWC measure had a NPV > 0, then it was worth considering on its economic merits otherwise it failed to return benefits greater than the value of resources used.

(ii) Benefit Cost Ratio (BCR): BCR was computed as the present value of benefits divided by the present value of costs. The discounted benefits and the discounted costs were calculated and summed separately, then divided. BCR was defined as
\[
BCR = \frac{\sum_{t=1}^{T} \left( \frac{Benefit_t}{(1 + r)^t} \right)}{\sum_{t=1}^{T} \left( \frac{Cost_t}{(1 + r)^t} \right)}
\]

Where \( r \) is the discount rate and the discounted:

- Benefits at time \( t \) = \( \sum_{t=1}^{T} \left( \frac{Benefit_t}{(1 + r)^t} \right) \) .................................2b
- Costs at time \( t \) = \( \sum_{t=1}^{T} \left( \frac{Cost_t}{(1 + r)^t} \right) \) .................................2c

If the SWC measure had a \( BCR > 0 \), then it was worth considering on its economic merits otherwise it failed to return benefits greater than its costs.

RESULTS AND DISCUSSION

Characteristics of Studied Households

A total of 433 households, having 2621 inhabitants (49% females), were interviewed (Table 1). The population of the households in the age bracket 16-59 years represented 30-36% of total population studied. This is the productive age bracket with a potential to provide labour for farming activities including SWC activities. Male headed households are dominant, implying the necessity to include men in soil and water conservation interventions at farm level. Furthermore, the total population comprise 49% females indicating that in addition to targeting males, females also need to be included in decision making processes on SWC. The main occupation of household heads in the study area is farming family fields. Other occupations include off-farm employment (casual labour for farming) and other types of off-farm employment in private and government sectors.

LH=Lower Highlands; UM = Upper Midlands; LM =Lower Midlands.

Table 1: Characteristics of studied households in three sub-catchments of Upper Tana, Kenya

<table>
<thead>
<tr>
<th>Description</th>
<th>Lower Chana</th>
<th>Kayahwe</th>
<th>Tungu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area of sub-catchment (km²)</td>
<td>750</td>
<td>124</td>
<td>111</td>
</tr>
<tr>
<td>Rainfall (mm/year)</td>
<td>1200-1500</td>
<td>800-1200</td>
<td>800-1500</td>
</tr>
<tr>
<td>Agro-ecological zones covered</td>
<td>Tea-Dairy Zone (LH1)</td>
<td>Tea-Dairy Zone (LH1)</td>
<td>Tea-Dairy Zone (LH1)</td>
</tr>
<tr>
<td></td>
<td>Tea-Coffee (UM1)</td>
<td>Tea-Coffee (UM1)</td>
<td>Tea-Coffee (UM1)</td>
</tr>
<tr>
<td></td>
<td>Main Coffee (UM2)</td>
<td>Main Coffee (UM2)</td>
<td>Main Coffee (UM2)</td>
</tr>
<tr>
<td></td>
<td>Marginal Coffee (UM3)</td>
<td>Marginal Coffee (UM3)</td>
<td>Marginal Coffee (UM3)</td>
</tr>
<tr>
<td>Number of households</td>
<td>148</td>
<td>152</td>
<td>133</td>
</tr>
<tr>
<td>Population in age bracket 16-59 years (% of total)</td>
<td>35</td>
<td>36</td>
<td>30</td>
</tr>
<tr>
<td>Household heads</td>
<td>86</td>
<td>88</td>
<td>81</td>
</tr>
<tr>
<td>(% of total)</td>
<td>77</td>
<td>92</td>
<td>86</td>
</tr>
<tr>
<td>Literate household heads (% of household heads)</td>
<td>68</td>
<td>84</td>
<td>79</td>
</tr>
<tr>
<td>Farming family fields (%)</td>
<td>17</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>In off-farm employment-farming (%)</td>
<td>14</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>In other off-farm employment</td>
<td>0.84 (0.9)</td>
<td>1.00 (0.9)</td>
<td>0.88 (0.8)</td>
</tr>
<tr>
<td>Average land holdings</td>
<td>0.01 (0.1)</td>
<td>0.07 (0.3)</td>
<td>0.05 (0.4)</td>
</tr>
</tbody>
</table>

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Land in the three sub-catchments is either held under individual tenure (freehold ownership) where land adjudication had been completed or as trust land (held in trust by County Councils on behalf of local communities until such a time that the land will be sub-divided into individual holdings). The per-capita land has been on the decline due to increasing population pressure and land fragmentation. The land holdings of the studied households were variable across the three sub-catchments and ranges from 0.6 to 1.3 hectares per household. The general slopes in the three sub-catchments range from gentle to moderate (slopes less than 25%), steep (slopes 25-55%) and very steep (slopes >55%). About 94% of all farms studied were in the slope range of gentle-to-moderate (< 25%) to steep (36-55%). The steepest slopes are found in farms in the Tea-Dairy zone followed by farms in the Tea-Coffee and main Coffee zones. This makes the farms in these areas very susceptible to soil erosion where there are no SWC measures, where inherent soil erodibility is high (e.g. in lower middle zones) and where there is lack of adequate vegetation cover.

**Labour for Investment, Establishment and Maintenance of SWC measures**

Labour and materials are part of investments that farmers make in establishing conservation measures. For structural measures, investment labour includes labour for establishing stabiliser grasses (except for stone lines in this study). Average labour for establishing grass stabilisers on structural measures was determined to be 28 labour days/ha. Labour for investment in structural measures is presented in Table 2 exclusive of labour for establishing grass stabilisers to aid comparison with frequently reported labour in literature.

| Table 2: Investment, establishment and annual labour for maintaining conservation measures |
|---------------------------------------------------------------|-----------------|------------------|
| **Investment/establishment (days/ha)** | **Annual maintenance (days/ha)** |
| **Structural measures (excluding stabilisers)** | | |
| Bench terrace | 263 | 58 |
| Fanya juu | 186 | 41 |
| Cut-off drain | 210 | 39 |
| Infiltration ditch | 208 | 72 |
| Stone lines | 67 | 10 |
| **Non-structural measures** | | |
| Trashlines | 22 | 0 |
| Grass strips | 58 | 82 |

Annual labour for establishment of trash lines included, has no maintenance labour

The labour requirement for establishing bench terraces were within range of 66-354 labour days/ha reported for stable soils at slopes of 5-55% in West Usambara Highlands of Tanzania (Tenge et al., 2005). Other studies in Eastern Kenya have reported 253-310 labour days/ha for construction of bench terraces (Wall, 1981). The labour demand for establishing bench terraces can go up to 500 labour days/ha as reported in the Philippines (Cruz et al., 1988). The results of this study are in agreement with previous work on labour demand for fanya juu terraces. Labour demand for establishing fanya juu of 43-281 days/ha was reported in Tanzania for stable soils with slopes of 5-55% (Tenge et al., 2005) while 136-281 labour days/ha with slopes of 5-35% was reported in Central Kenya (Wenner, 1980). Comparative labour demand of 84-150 labour days/ha and 205 labour days/ha was reported in Eastern Kenya and in Peru, respectively, for establishing fanya juu terraces (Wall, 1981; Barret, 1985; Alfaro-Moreno, 1987).

The labour demand for stone lines in this study was within the range of 51-166 days/ha reported in Burkina Faso where the stones were fetched 2 to 4 km away using lorry or donkey carts to build 200 to 400 meres/ha of stone rows (De Graaf, 1996). It was also comparable to labour for constructing stone terraces in Eastern Kenya of 36 and 62 days/ha for small and large stone bunds respectively (Ellis-Jones and Tengberg, 2000). Other authors have reported 219 labour days/ha where farmers dig trenches before placing the stones to "build the stone bund", thus incurring more labour (Rochette, 1989). The labour for constructing structural measures of SWC differs in literature due to different circumstances and techniques involved and distances where the stones have to be fetched from.

The labour demand for establishing non-structural measures was lower than that of establishing structural measures with trash lines having the lowest. Contour tillage and planting (contour farming) and contour ridging are made every planting season; thus these were considered to have variable costs rather than long-term investment costs. However, Napier grass strips and trash lines have costs associated with establishment. The labour requirement for establishing Napier grass strips was within range of 7-59 day/ha reported in literature (Tenge et al., 2005). Labour demand of 22 labour days/ha for establishing trash lines was comparable to 10-20 labour days/ha reported in Eastern Kenya (Ellis-Jones and Tengberg, 2000).
Annual maintenance labour varied greatly from one conservation practice to the other with grass strips, infiltration ditch and bench terraces attracting highest labour demand for maintenance. The latter two are due to frequent scooping of soil out of the excavated ditch while for Napier Grass strip, it was due to frequent cutting of the grass to feed livestock and the necessity to carry out frequent good agronomic practices to keep yields high.

**Benefits and Profitability of Structural SWC Measures in the Year of Study**

The yields of maize grains observed in this study were lower than expected yields (2.5 to 7 tonnes/ha) for common maize varieties planted in the study area (MoARD, 2002) except for comparable yields attained with stonelines (Table 3). The differences in yields are a reflection of differences in farmer’s management levels. With better management, higher yields can be attained subject to availability of adequate soil moisture. Similarly, the yields of beans obtained in this study were lower than potential yields of 1-2 tonnes/ha for field bean varieties planted in the study sites (MoARD, 2002). An improvement in crop management would result in higher yields and gross margins. It is noted that farmers using stone-lines in the lower midland zones (marginal coffee zone; cotton tobacco zone) of this study appeared to have reported exceptionally higher grain yields. Previous studies have indicated that maize grain yields rarely reach 2 tonnes/ha in these areas (Onduru and Du Preez, 2008).

<table>
<thead>
<tr>
<th>Description</th>
<th>Bench terrace</th>
<th>Fanya juu</th>
<th>Cut-off drain</th>
<th>Infiltration ditch</th>
<th>Stone lines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize grain yields (kg/ha)</td>
<td>1636</td>
<td>56,097</td>
<td>1547</td>
<td>39216</td>
<td>61877</td>
</tr>
<tr>
<td>Beans grain yields (kg/ha)</td>
<td>196</td>
<td>19,844</td>
<td>369</td>
<td>20482</td>
<td>396</td>
</tr>
<tr>
<td>Sub-total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crop residues (Ksh)</td>
<td>75,941</td>
<td>59,698</td>
<td>74,467</td>
<td>51,174</td>
<td>148,378</td>
</tr>
<tr>
<td>Napier grass (FM kg/ha)</td>
<td>145461</td>
<td>102841</td>
<td>369167</td>
<td>18893</td>
<td>357360</td>
</tr>
<tr>
<td>Gross income</td>
<td>461,189</td>
<td>7</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maize/beans-production costs</td>
<td>567,476</td>
<td>454,030</td>
<td>421,130</td>
<td>430,636</td>
<td>215,107</td>
</tr>
<tr>
<td>Napier grass-production costs</td>
<td>251,121</td>
<td>164004</td>
<td>130232</td>
<td>137798</td>
<td>78480</td>
</tr>
<tr>
<td>Establishment cost of structure-annuity</td>
<td>9788</td>
<td>7531</td>
<td>8243</td>
<td>8189</td>
<td>8602</td>
</tr>
<tr>
<td>Annual maintenance cost of structure</td>
<td>8700</td>
<td>6150</td>
<td>5850</td>
<td>10950</td>
<td>1500</td>
</tr>
<tr>
<td>Total costs</td>
<td>371,064</td>
<td>279,140</td>
<td>245,780</td>
<td>258,392</td>
<td>88,582</td>
</tr>
<tr>
<td>Total labour days</td>
<td>753</td>
<td>543</td>
<td>524</td>
<td>764</td>
<td>252</td>
</tr>
<tr>
<td>Gross margins (GM)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BCR (undiscounted)</td>
<td>196,412</td>
<td>174,890</td>
<td>175,350</td>
<td>172,244</td>
<td>126,525</td>
</tr>
<tr>
<td>GM/Labour day</td>
<td>261</td>
<td>322</td>
<td>335</td>
<td>225</td>
<td>502</td>
</tr>
</tbody>
</table>

Qty = Quantity; Values are in Ksh/ha; 1 US$ = Ksh 88; BCR = Benefit Cost Ratio; FM = Fresh matter

Assuming a dry matter fraction of 0.14 for Napier (Wouters, 1987), yields obtained in this study were higher for infiltration ditches (32.1 tonnes DM/ha) and Cut off drains (26.5 tonnes DM/ha) than for bench terraces (20.4 tonnes DM/ha) and fanya juu terraces (14.4 tonnes DM/ha).

The gross margins in the year of the study were positive for all structural measures studied indicating the viability of these practices. The highest gross margins were achieved using bench terraces while that of *fanya juu*, cut-off drains and infiltration ditches were comparable in the year of the study. Lowest gross margins were achieved in conserved land areas with stone-lines. The gross margins per Labour Day were also positive for all practices studied and were above the opportunity costs of labour (Ksh 150-200) in the study sites, indicating positive returns.
Financial Cost Benefit Analysis of Structural SWC measures

The year of establishing the SWC structure was considered base year (year 0) and successive years (up to 15th year) were considered in calculating Net Present Value (NPV). The results of the study show that the SWC structures studied will begin to pay-off, in financial terms, in year one-to-two after the base year (i.e. second to third calendar year after establishment), by which time the accumulative Net Present Value (NPV) becomes positive and the cost of the investment would have been recovered (Table 4). The short time taken to realise positive financial returns is due partly to grasses planted on the terrace embankments and risers, mainly the high value Napier grass used as fodder for dairy animals. In most parts of Upper Tana with high rainfall, Napier takes about 12-13 weeks from date of planting to first cut. Reports by de Graaf (1996) indicate that earth bench terraces and stone-lines take about 2 years and less than one year respectively to become effective.

Table 4: Financial efficiency of studied SWC structural measures (15-year time horizon; values for NPV x 1000)

<table>
<thead>
<tr>
<th>Discount rate</th>
<th>Bench terrace</th>
<th>Fanya juu</th>
<th>Cut-off drain</th>
<th>Infiltration ditch</th>
<th>Stone lines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time elapse after base year*</td>
<td>10%</td>
<td>2009.9</td>
<td>1844.4</td>
<td>1848.4</td>
<td>1826.5</td>
</tr>
<tr>
<td></td>
<td>12%</td>
<td>1784.7</td>
<td>1638.1</td>
<td>1641.2</td>
<td>1621.7</td>
</tr>
<tr>
<td></td>
<td>14%</td>
<td>1595.4</td>
<td>1464.7</td>
<td>1467.0</td>
<td>1449.4</td>
</tr>
<tr>
<td>BCR</td>
<td>10%</td>
<td>1.1</td>
<td>1.4</td>
<td>1.3</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>12%</td>
<td>1.1</td>
<td>1.3</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td>14%</td>
<td>1.1</td>
<td>1.3</td>
<td>1.2</td>
<td>1.2</td>
</tr>
</tbody>
</table>

*Refer to time elapse after the base year before positive financial returns are attained; to get calendar years elapsing before being effective, add one calendar year. NPV = Net Present Value; BCR = Benefit Cost Ratio; 1 US$ = Ksh 88

The NPV for bench terraces was higher than those of other structural measures (fanya juu, cut-off drain, infiltration ditches and stone lines) considered in this study (Table 4). Similar trends have also been reported by Tenge et al., (2005) in West Usambara highlands, Tanzania. However, it is to be noted that the profitability of bench terraces, as is the case for other types of terraces, depend on management level of the farmer and whether high value crops have been grown. The decision criteria used in this study were noted to be sensitive to discount rates with high discount rates resulting in low NPV values. The practices studied were viable and financially attractive (BCR of 1 and higher).

Financial Cost Benefit Analysis of Structural SWC Measures at Different Time Scales

Analysis was extended to include planning periods of 30, 60 and 90 years and the effects of different discount rates on returns to SWC measures calculated. Planning periods of 60 and 90 years constitute a problem of inter-temporal external effects touching on future generations. In previous studies, some authors have used a planning period of 75 years in calculations of streams of benefits for present generation while others have used 25 years for current generation and 50 years for the next two generations (Walker, 1982). Results from this analysis indicate that the discount rate chosen influences the distribution of costs and benefits of SWC to future generations with higher discount rates resulting in low benefits for a given time horizon of analysis (Table 5). It has been noted elsewhere that most poor smallholder farmer’s individual time preference rates (the rate at which individuals are willing to trade present for future consumption) may rise to high levels where it becomes meaningless to refer to them in cost benefit analysis due to farmers current pressing need for food, water and firewood (Riezebos, 1989). This partly explains exploitative patterns of land use and the farmers’ unwillingness, incapability or disinterest on investing in resource conservation for the future (Dixon and Fallon, 1989). However, some authors have noted that it may not be true that decision making by smallholders is generally guided by short-term thinking since farmers also grow perennial crops that bring returns in the long term (Enters, 1998).

The results of this study further shows that at each time horizon of analysis and at a given discount rate, net present value (NPV) for bench terrace was higher than the rest of structural SWC measures. Also for all conservation measures, the Benefit Cost Ratio (BCR) was greater than zero, indicating that they were economically worth investing in.
Table 5: Net Present Value (NPV) and Benefit Cost Ratio (BCR) of selected conservation measures at different time scales

<table>
<thead>
<tr>
<th>Time (Years)</th>
<th>NPV (x 1000)</th>
<th>BCR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>Rate (%)</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>NPV (x 1000)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bench terrace</td>
<td>2,525</td>
<td>2,137</td>
</tr>
<tr>
<td>Fanya juu</td>
<td>2,317</td>
<td>1,961</td>
</tr>
<tr>
<td>Cut-off drain</td>
<td>2,323</td>
<td>1,965</td>
</tr>
<tr>
<td>Infiltration</td>
<td>2,296</td>
<td>1,942</td>
</tr>
<tr>
<td>Ditch</td>
<td>985</td>
<td>833</td>
</tr>
<tr>
<td>Stone line</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>BCR</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Cut-off drain</td>
<td>1.4</td>
<td>1.4</td>
</tr>
<tr>
<td>Infiltration</td>
<td>1.3</td>
<td>1.3</td>
</tr>
<tr>
<td>Ditch</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

NPV = Net Present Value; BCR; 1 US$ = Ksh 88

Analysts are divided on how to determine future costs and benefits for future generations, use of discount rates, levels of discount rate to use and whether other methods should be applied instead, for example in conditions where environmental degradation is irreversible (Hubacek & Mauerofer, 2008; Porter, 1982). This is because the values of future costs and benefits on which the NPV is based are forecasts that cannot be known with certainty, money has opportunity costs (money received now can be re-invested), and the process of discounting makes distant costs and benefits insignificant relative to the present. Other authors have also proposed the determination of NPV using multiple base years, for example using year 30 as base year to approximate benefits from the point of view of next generation (Cooper, 1981; De Janvry et al., 1994). However, it is increasingly becoming clear that financial analysis based on market mechanisms, such as cost benefit analysis has not been able to deal sufficiently with equity considerations, namely intra-generational equity (social equity and interregional equity) and intergenerational equity (De Graaf, 1996). In this case, social equity refers to fairness between social groups and interregional equity considers upstream-downstream effects and fairness within a time span of the same generation.

The results of this study further show that Net Present Value is sensitive to time scales of analysis with increasing time horizons resulting in marginal benefits at a constant discount rate (Table 5). The time horizon selected determines the temporal flow of benefits that need to be used in this generation and what needs to be distributed for future use. However, CBA framework does not provide guidelines as to how far into the future to predict benefits and how to make short-term and long-term tradeoffs between generations (Hundloe et al., 1990). Furthermore, most analysts fail to provide rationale for their choice of time horizon, which in past studies range from six to 100 years (Enters, 1998). However, other authors have reported that distant benefits should not be exaggerated by choosing a longer time horizon, since even extending the time horizon from 30 to 40 years have only a marginal effect on Net Present Value at a constant discount rate (Bojö, 1986).

**Benefits and Profitability of Non-structural SWC Measures in the Year of Study**

Analysis of data collected on non-structural measures (agronomic and cultural) of soil and water conservation show that gross margins were positive for all the practices studied and benefit cost ratios (undiscounted) were higher than one indicating that the practices were viable in the year of the study. The gross margins per labour day were also higher than the opportunity costs of labour except for contour tillage and planting. Napier grass strips attained higher gross margins per labour day than other vegetative and agronomic measures studied (Table 6).
### Table 6: Grain yields and gross margins per hectare achieved with SWC non-structural measures

<table>
<thead>
<tr>
<th>Description</th>
<th>Trash-lines Qty</th>
<th>Grass strips Qty</th>
<th>Contour planting + tillage Qty</th>
<th>Contour ridging Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize grain yields (kg/ha)</td>
<td>2112</td>
<td>980</td>
<td>1852</td>
<td>1675</td>
</tr>
<tr>
<td>Value</td>
<td>54,385</td>
<td>20,853</td>
<td>36986</td>
<td>41165</td>
</tr>
<tr>
<td>Beans grain yields (kg/ha)</td>
<td>25</td>
<td>336</td>
<td>139</td>
<td>114</td>
</tr>
<tr>
<td>Value</td>
<td>1,729</td>
<td>22,775</td>
<td>8035</td>
<td>8447</td>
</tr>
<tr>
<td>Sub-total</td>
<td>56,116</td>
<td>43,628</td>
<td>45,021</td>
<td>49,612</td>
</tr>
<tr>
<td>Crop residues (Ksh)</td>
<td>89,101</td>
<td>13,431</td>
<td>40,257</td>
<td>10,757</td>
</tr>
<tr>
<td>Napier grass (FM kg/ha)</td>
<td>228992</td>
<td>528728</td>
<td>188937</td>
<td>328072</td>
</tr>
<tr>
<td>Gross income</td>
<td>145,217</td>
<td>585,787</td>
<td>85,278</td>
<td>60,369</td>
</tr>
<tr>
<td>Maize/beans production costs</td>
<td>65,332</td>
<td>28,012</td>
<td>56,761</td>
<td>27,211</td>
</tr>
<tr>
<td>Napier grass production costs</td>
<td>0</td>
<td>105,955</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Establishment cost of Structure</td>
<td>0</td>
<td>94,190</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Annual maintenance cost of structure</td>
<td>16,935</td>
<td>24,300</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total costs</td>
<td>82,267</td>
<td>146,502</td>
<td>56,761</td>
<td>27,211</td>
</tr>
<tr>
<td>Total labour days</td>
<td>261</td>
<td>252</td>
<td>217</td>
<td>115</td>
</tr>
</tbody>
</table>

**Gross margins (GM)**

<table>
<thead>
<tr>
<th>Description</th>
<th>Trash-lines Qty</th>
<th>Grass strips Qty</th>
<th>Contour planting + tillage Qty</th>
<th>Contour ridging Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>62,950</td>
<td>439,285</td>
<td>28,517</td>
<td>33,158</td>
<td></td>
</tr>
<tr>
<td>BCR (undiscounted)</td>
<td>1.8</td>
<td>4.0</td>
<td>1.5</td>
<td>2.2</td>
</tr>
<tr>
<td>GM/Labour day</td>
<td>241</td>
<td>1743</td>
<td>131</td>
<td>288</td>
</tr>
</tbody>
</table>

| Qty = Quantity; Values are in Ksh ha⁻¹; BCR = Benefit Cost Ratio; GM=Gross margins; 1US$= Ksh 88 |

### Financial Cost Benefit Analysis of Non-structural SWC measures

Cost benefit analysis of non-structural measures were assessed over a 15-year time horizon and were not extrapolated to time horizons that span more than one generation since agronomic and non-structural measures usually have shorter time spans than structural measures. Results of the study (Table 7) show that net present values (NPV) are sensitive to discount rates with higher rates resulting in low NPV just like for the structural measures. The time elapsed before positive results (NPV) were obtained for non-structural measures was less than one year i.e. the conservation measures were effective in the year of establishment.

<table>
<thead>
<tr>
<th>Discount rate</th>
<th>Trash-lines</th>
<th>Grass strips</th>
<th>Contour tillage + planting</th>
<th>Contour ridging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time elapse after base year*</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>NPV</td>
<td>10% 526.5 3962.7</td>
<td>214.9 250.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12% 589.9 3538.6</td>
<td>192.3 223.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14% 473.1 3181.9</td>
<td>173.4 201.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BCR</td>
<td>10% 1.1 8.0</td>
<td>0.5 1.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12% 1.1 7.8</td>
<td>0.5 1.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14% 1.1 7.6</td>
<td>0.5 1.2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Refer to time elapse after the base year before positive financial returns are attained; Are effective in the year of establishment. NPV= Net Present Value; BCR = Benefit Cost Ratio; 1 US$= Ksh 88

The NPV and BCR values for grass strips (Napier grass strips) were much higher than the rest of the practices. The grass strips were mainly Napier bunds, which are of high value as fodder. This observation further indicates that the viability of the practices studied depend partly on the type of crop planted, with high value crops bringing higher returns.
The financial Cost Benefit Analyses have corroborated farmers qualitative perceptions collected during this study that both structural and non-structural conservation measures are beneficial. Farmers reported benefits derived from SWC measures to include conservation of soil/reduction of erosion; provision of fodder from stabilizer grasses; increases in crop production; improvement/maintenance of soil fertility; conservation of moisture; provision of income from sale of fodder, timber and other crop products; control of run-off and increase in infiltration; harvest of water for crop production; and stabilization of river banks.

Sharing of Conservation Benefits between Generations-Intergenerational Equity Assessments

Balancing the needs of future generation with the needs of the present generation regarding benefits of conservation is a debate in public domain; partly because persons not yet born have no say on present activities that may affect them and partly due to ethical reasons on what should be passed on to the next generation as conservation benefits. There are two viewpoints on sustainability proposing how intergenerational equity on benefits of conservation can be achieved - weak sustainability and strong sustainability. Proponents of weak sustainability believe that natural resources can be used to create wealth in such a way that the total aggregate quantity and quality of the resource is not changed from one generation to the next; and where an attribute of the natural resource is changed, it can be substituted by manufactured capital (machinery, tools, infrastructure etc.) (Hartwick, 1977; Solow, 1974; Ekins et al. 2003). In this view, all generations have an equal opportunity to create wealth and future generations will not suffer environmental loss as it shall be compensated for by wealth creation. Future generations are believed to bequeath alternative ways of wealth creation and therefore will have same opportunity to create wealth from natural resource (capital) as the present generation and so should not be given preferential treatment (Beder, 2000). Future generation bequest packages that include reproduced capital, technological capacity, natural resources and environmental quality that enables them to create wealth (Howarth, 1997).

Proponents of strong sustainability believe that nature offers more than just economic potential and thus cannot be substituted by manufactured capital and argue that future generations should not inherit a degraded environment, no matter how many alternative ways of creating wealth will be at their disposal. Many reasons exist to prefer strong sustainability: many natural assets have no substitutes (ozone layer, intrinsic value of animals etc.); the scientific knowledge about functions of natural ecosystems is incomplete and degradation may lead to irreversible losses of some species and habitats, which cannot be recreated or substituted by manufactured capital; and losses of natural resources may take centuries to be restored e.g. soil degradation. However, some authors have postulated that it is possible to address the problem of intergenerational equity by starting with the concept of strong sustainability but recognising substitutability of capital where the welfare derived from natural capital is fully commensurable with other welfare from production (Ekins et al., 2003).

Another way of analysing how equity can be attained in sharing conservation benefits between generations is the use of discount rates. For medium term projects (30-40 year time horizon), Kopp and Portney (1999) emphasize that cost-benefit analysis and the discounting approach can be used to make decisions on environmental effects. However, there is a debate on the role of discount rates and its relevance when assessing intergenerational equity in situations where development interventions exhibit environmental externalities and where impacts are felt in the long-term (Markandya and Pearce, 1988). Many natural resource and environmental problems have adverse effects in the medium or long term thus affect individuals who have little or nothing to do with the decisions that caused them - these problems are “environmental externalities” between generations (Pasqual and Souto, 2003). While some authors argue for the use of discount rates to assess intergenerational equity (Arrow K., 1999), others caution their use (Sáeza and Requena, 2007) and yet others report that discount rates is not the problem but the failure of many analysts to correctly evaluate the costs and benefits of conservation that accrue to future generations (Neumayer, 1999). The problem is a methodological one dictated by perceptions on intergenerational ethics and moral obligations for future generations.

In a workshop organised by the Energy Modelling Forum of Stanford University and the Resources for the Future (Washington, DC) to discuss issues of discounting in decision problems affecting the very long-term future, opinions stood divided on the use of discount rates and its relevance (Portney and Weyant, 1999). Those who propose to use discount rates to assess intergenerational equity derive their arguments from diverse models and believe that any generation will tend to treat itself better and despite recognitions of moral arguments about the welfare of future generations, discounting should follow standard procedures even for long-term projects. For example, Arrow (1999) maintains that whether discounting makes development initiatives pay-off in the far future is largely an ethical problem. He observes that although individuals recognize moral arguments about their responsibilities for future generations, they tend to treat themselves better. From models constructed where each generation is selfish, he concludes that there is no need to use preferential discount rates even the use of lower rates in assessing intergenerational equity regarding conservation and environmental benefits. Using different lines of thinking and models, the same conclusions were arrived in Bradford (1999), Montgomery (1999), and Manne (1999).

Dasgupta et al. (1999) takes a closer look at the logic underlying social discount rates and argues that investments with long-run effects should be investigated with the same conceptual treatments as “normal”, short-
run projects. Using a simple model example of climate change, they reject the idea of sector specific discount rates, i.e., the preferential treatment of environmental investments even for future generations.

Pearce (1990) corroborates the above views by reporting that there should be no decrease in environmental capital stock between generations whatever the circumstances and that the total sum of environmental damage caused by projects should be compensated by side-projects (shadow projects) initiated for this purpose; and therefore there is no need to adjust discount rates in favour of environmental externalities as this amounts to double accounting.

Some authors believe that the theory of discounting is incompatible with the idea of sustainability for it translates into undervaluing the future. By discounting the future we make the future generations preferences count less than our own (Pearce and Turner, 1990). Discounting devalues the impacts that occur in the distant future resulting in conservation projects with distant costs and prompt benefits being favoured while future benefits are devalued and externalities not taken into account (Padilla, 2002). There are externalities between generations since future generations do not participate in the current decisions.

Authors who believe that discount rates should not be used in assessing intergenerational equity have proposed to vary discount rates when dealing with environmental externalities, retain the discount rate as it is but increase the value of the environmental goods with time and the use of other approaches that take future generations into account (Sáeza and Requena, 2007). Those who believe that there should be variations in discount rates when assessing intergenerational equity have different perspectives: use of a discount rate of zero to prevent the present generation from ignoring the long term effects of the environment (Shue, 1999); application of constant but lower rate in favour of the environment, though this has been a subject of debate (Padilla, 2001); use of varying discount rates and lowering the rates with time (Azar and Sterner, 1996); and using empirically derived discount rates by asking the present generation their opinions on intergenerational equity as well as conducting empirical work.

Approaches to assessing intergenerational equity without modifying discount rates include (i) employing traditional social discount rate at constant rate, but increasing the value of environmental asset with time on the basis that natural resources become scarce with time and therefore expensive (Fisher and Krutilla, 1985); (ii) the use of intergenerational weights in CBA to ensure fairness between generations (Kula, 1988; Padilla and Pascual, 2002; Fearnside, 2002) and (iii) the use of intergenerational discount factor (Sumaila and Walters, 2005). Other authors believe that irrespective of methods adopted in intergenerational equity assessments, success in arriving at intergenerational equity on conservation benefits will not be attained unless functional institutions are established, with capacity to impose incentives and sanctions and to foster the rights of future generations (Padilla, 2002).

Limitations of the Study

This study applied cost benefit analysis tool to establish a guide for investment decision on structural and non-structural (agronic and cultural) soil and water conservation measures. CBA measures the costs and benefits in a situation with conservation measure and one without conservation measure. Application of CBA in this study was faced with the following challenges: valuation of non-traded goods and services, the choice of discount rate and time horizon for analysis and the application of CBA in intergenerational equity assessments. In this study, non-traded items like family labour and non-traded materials for construction and maintenance of soil and water conservation practices were valued at opportunity costs determined by either asking the farmer or using estimates in the study area. Although this valuation approximates reality, it cannot be considered to be the true economic value of family labour and materials valued, which can only be obtained where the items are traded and a real market value exists. Some analysts have noted that despite the remarkable development in valuing non-traded items, attaching accurate and true costs to environmental goods and service remains unresolved and the value of a cost-benefit analysis will vary depending on the accuracy of the individual cost and benefit estimates (Balana et al., 2012). CBA to some extent is based on the weak sustainability principle where there is substitutability of capital and therefore all capital can be expressed in same monetary unit (Faucheux and O'Connor, 1998).

The choice of discount rate and time horizon in this analysis is subject to debate. The discount rate should reflect the reality of the economic environment as much as possible, but in application its selection remains subjective with a lower rate bringing higher streams of benefits to future generations than a higher rate (Stiglitz, 1994). This study used an average interest rate payable by farmers when securing a bank loan at the time of the study as the discount rate. Since farmers do not access loans from the same banks with uniform interest and pay-back periods and since some of the smallholders who participated in this study have no access to bank loans due to various constraints, the discount rate used in this study remains contestable. It gives a general picture rather than farmer-specific situation. Similarly, the time horizon of analysis influences the outcome of CBA since the flow of benefits of soil and water management practices, especially structural practices, are realized in the long term. Thus, the use of a shorter time horizon in the analysis results in questionable results while longer time horizons are incompatible with smallholder planning time frames. Smallholders tend to plan their activities over a short time period given the high risks and insecure environment they are faced with (Kappel,
The lowest time horizon of 15 years used in this study approximates the life span of structural soil and water conservation practices before farmers re-invest in them again; but in reality the time span of some of the practices may be shorter than this while others are longer depending on how they are maintained.

Similar studies elsewhere have also noted flaws in using CBA to include the risk of quantifying variables that ethically should not be “moneterised”, that CBA uses aggregate values that tend to hide the specifics and that there is a potential risk of using CBA to manipulate results to underpin preconceived notions (Bojö, 1992). Other authors have also noted that the use of many decision criteria in CBA sometime result in conflicting results (Prince and Nair, 1984; Trivedi, 1986). In using CBA, the four commonly used decision criteria, that allow costs and benefits to occur in streams spread over time, include internal rate of return (IRR), benefit-cost ratio (BCR), net present value (NPV) and net benefit-investment ratio (Gittinger, 1982; Bojö, 1986). Among the four criteria, some reviewers recommend NPV alone as the best all-round selection criterion to use and the most straightforward (Wasberg, 1989; Gittinger, 1982). However, despite its limitations, this study has shown that CBA still remains an important analytical tool in analysing soil and water conservation benefits and in making relevant decisions, but should be applied with appropriate care.

This study used the change in productivity approach where the erosion damage is equated to the value of lost crop yields valued at market rates and the net benefits of SWC measures are estimated based on quantifying crop yields when erosion is taking place (without conservation measure) and yields when erosion has been controlled (with conservation measure). The limitation with this method is that it assumes that crop production can be done in a situation without erosion when soil and water conservation measures are present. However, it is known that no technology exist to produce a crop without some degree of erosion. Another assumption of the method is that yields of crops and gross revenues in farms without erosion can be stable and maintained forever while in practice it may not be the reality (Enters, 1998).

CONCLUSIONS

Labour and materials are key inputs required for establishing structural and non-structural conservation measures. This study has shown that depending on prevailing market prices and opportunity cost attributed to labour, other inputs and crop type (high value or subsistence low value) planted on conserved land, the conservation measures can either take a short or a longer period before positive financial returns are attained from the base year of investment. High value fodder crops planted to stabilise SWC structures and those planted in conserved land, reduces the time period taken for the conservation structures to pay-off to one-two calendar years depending on the conservation measure. Thus it is recommended that the implementation of structural conservation measures, associated with high initial capital input, be accompanied by establishment of appropriate high value and fast growing stabiliser fodder grasses, trees or shrubs etc. and that the conserved land be planted with high value crops to raise the level of returns from conservation measures and to reduce the pay-back period.

Financial cost benefit analysis conducted in this study have shown that both the structural and non-structural conservation measures studied are financially attractive with positive gross margins in the year of study; and net present value and benefit cost ratio being positive and greater than zero. The net present value for bench terraces was higher than those of other structural measures (fanya juu, cut-off drain, infiltration ditches and stone lines). Similarly, the net present value and benefit cost ratio for Napier grass strips were higher than the rest of the non-structural measures (trash-lines, contour tillage + planting (contour farming) and contour ridging). However, it is to be noted that financial efficiency alone may not be sufficient to increase level of investment in soil and water conservation practices. Considerations of institutional set-ups that draw expertise from various relevant stakeholder organisations, inclusion of credit policies that enhance smallholders’ access to inputs and credit and other factors of adoption such as conducive land tenure are also required.

One of the major hindrances for farmers to adopt soil and water conservation measures is the time lag between investments and the return of benefits, especially for structural measures. Experiences from this study tend to show that there is need to combine structural measures which bring returns in the long-term with conservation measures that are profitable in the short term to address farmers’ needs. Structural measures can be combined with non-structural ones, for example, early planting, planting of fodder grass strips, quick maturing fodder and shrubs, use of contour ridges etc. These strategies can further be combined with judicious management of organic and inorganic sources of fertility to improve productivity gains on conserved land.

Financial cost benefit analysis (CBA) framework allows for comparison among alternative soil and water conservation practices over a given time horizon based on a selected discount rate and has implication on what level of benefits the current generation is willing to have (intra-generational equity) and what benefits they will pass over to future generations (intergenerational equity). Analysis at 15, 30, 60 and 90 year time horizons and at different discount rates (10%, 12% and 14%) have shown that the higher the discount rate, the less are the streams of benefits and at a constant discount rate, a longer time horizon of analysis results in marginal benefits bringing into question whether conventional CBA analyses can be applied in intergenerational equity assessments and whether it is appropriate to extrapolate analyses to 60 and 90 year time horizon given the
lifespan of most land use practices. It is recommended that future studies explore alternative methodologies of analyses, for example varying discount rates and the use of generational weighting factors among others, to contribute to the debate on intergenerational equity and benefits of soil and water conservation measures.

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