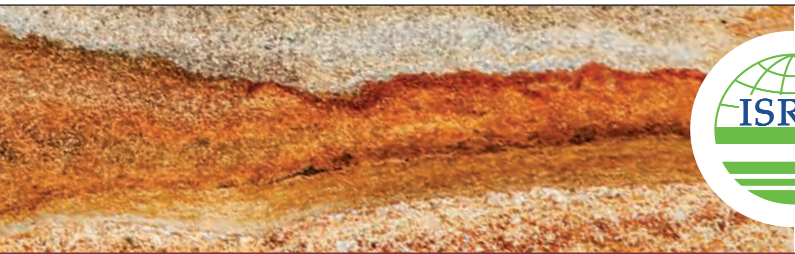
Cost Benefit Analysis of Land Management Options in the Upper Tana, Kenya



World Soil Information

Green Water Credits Report 15

D.D. Onduru and F.N. Muchena

Green Water Credits

Cost-Benefit Analysis of Land Management Options in the Upper Tana, Kenya

Authors
D.D. Onduru
F.N. Muchena

Series Editors
W.R.S. Critchley
E.M. Mollee

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Director, ISRIC – World Soil Information
PO BOX 353
6700 AJ Wageningen
The Netherlands
E-mail: soil.isric@wur.nl

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The assignments were carried out by: Davies Onduru, Fred Muchena and Esther Njuguna
The contributions by farmers, ISRIC and all organisations to this report are highly appreciated
Submitted by ETC East Africa Ltd
ABC Place, Waiyaki Way
P.O. Box 76378, Nairobi, Kenya
Phone: ++254 (0)20 4 445 421/2/3 - Fax: ++254 (0)20 4 445 424
E-mail: office@etc-eastafrica.org

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ETC East Africa Ltd
ABC Place, First Floor Wing One, Waiyaki Way, P.O. Box 76378-00508 Nairobi, Kenya
Phone: ++254 (0)20 44 45 421/2/3 - Fax ++254 (0)20 44 45 424
Website: www.etc-international.org
E-mail: etc-ea@africaonline.co.ke

ISRIC World Soil Information

Green Water Credits Report 15

Foreword

ISRIC – World Soil Information has the mandate to create and increase the awareness and understanding of the role of soils in major global issues. As an international institution, ISRIC informs a wide audience about the multiple roles of soils in our daily lives; this requires scientific analysis of sound soil information.

The source of all fresh water is rainfall received and delivered by the soil. Soil properties and soil management, in combination with vegetation type, determine how rain will be divided into surface runoff, infiltration, storage in the soil and deep percolation to the groundwater. Improper soil management can result in high losses of rainwater by surface runoff or evaporation and may in turn lead to water scarcity, land degradation, and food insecurity. Nonetheless, markets pay farmers for their crops and livestock but not for their water management. The latter would entail the development of a reward for providing a good and a service. The Green Water Credits (GWC) programme, coordinated by ISRIC – World Soil information and supported by the International Fund for Agricultural Development (IFAD) and the Swiss Agency for Development and Cooperation (SDC), addresses this opportunity by bridging the incentive gap.

Much work has been carried out in the Upper Tana catchment, Kenya, where target areas for GWC intervention have been assessed using a range of biophysical databases, analysed using crop growth and hydrological modelling.

Part One of this report presents a study of **on-site** costs and benefits of selected soil and water conservation practices ("*green water* management measures" as termed under GWC) that was carried out among smallholder farmers in the Upper Tana. The returns to investment, over a 15-year period, were determined using net present value, benefit-cost ratio and incremental net benefits (at discount rates of 10, 12 and 14%), and internal rate of return. Addressing needs in a holistic way requires a "Commercial Sustainable Investment Package" for smallholders. The main requirements for such a package are presented and described in this report.

Part Two of the report comprises a study of costs and benefits of **off-site** impacts of the selected soil and water conservation measures – this time conducted among five large water users along the Tana River. The study focused on KenGen, Delmonte, Kakuzi, Nairobi City Water and Sewerage Company as well as the small-scale irrigators along the Yatta Canal. The study has shown that soil and water conservation practices in the Upper Tana catchment lead to benefits that accrue to the institutions, and these make the Green Water Credits programme worthy of investment.

Dr ir Prem Bindraban
Director, ISRIC – World Soil Information

PART I
COSTS AND BENEFITS OF SOIL AND WATER CONSERVATION PRACTICES: ON-SITE

Key Points

- A study of costs and benefits of selected soil and water conservation practices ("*green water* management measures" as termed under GWC) was carried out among 433 smallholder farmers in the Upper Tana, Kenya. The returns to investment, over a 15-year period, were determined using net present value, benefit-cost ratio and incremental net benefits (at discount rates of 10, 12 and 14%), and internal rate of return.

- Microcatchments with bananas, mulching in tea, zero tillage in coffee and riverine protection are profitable and viable, with net present value and benefit-cost ratios being positive and higher than one. Similarly, these are worth investing in as the internal rate of return is higher than the prevailing market interest rate.

- Structural measures of bench and *fanya juu* terraces, cut-off drains, retention ditches and stone lines return a positive net present value and benefit-cost ratio, and a high internal rate of return, demonstrating profitability. This was the case also for agronomic and vegetative measures including trash lines, grass strips, and contour farming.

- When high value fodder grasses are planted to stabilise SWC structures, then the time taken for the structures to pay off is shortened to one-two years. There are incremental gains when conserved land is planted with high value crops.

- Despite the positive indicators of this cost-benefit study, the implementation of SWC practices is not automatically carried out by farmers, because of the time lag between investments and returns. Thus, there is a need to combine structural measures with those – agronomic and vegetative - that are profitable in the short-term.

- Profitability of conservation structures depends on prices of inputs and outputs, technologies used and farmers' level of management. However, economic efficiency alone may not be sufficient to increase the level of investment in SWC practices. Expertise from relevant organisations and inclusion of credit policies that enhance smallholders' access to inputs are also required.

- There are capable extension service providers in the Upper Tana catchment who can train and provide technical assistance to farmers. However, the number of staff needs to be expanded, transport for staff must be addressed, and there is need to accompany awareness and technical training by adequate farmer support and incentives for the farmer to implement the practices.

- Addressing needs in a holistic way requires a "Commercial Sustainable Investment Package" for smallholders. The main requirements for such a package are:
  - Soft loans: because of the time lag between investment and return of benefits;
  - Support to develop an "entrepreneurial" farm plan, attractive to farmers;
  - Technical support: tailored to individual farm and natural conditions; and
  - Adequate institutional support: to make the investments operational.

Contents

Acronyms and Abbreviations

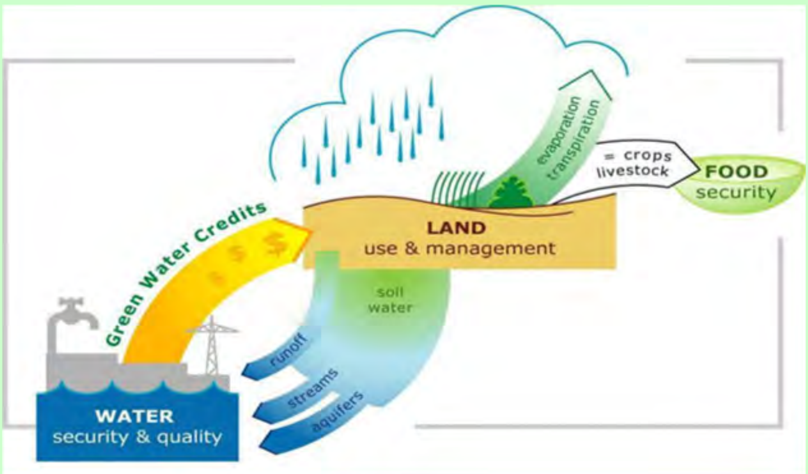
BCR	Benefit-Cost Ratio
CBA	Cost-Benefit Analysis
CBO	Community Based Organisation
CSIP	Commercial Sustainable Investment Package
FBO	Faith Based Organisation
FFA	Food-for-asset
GO	Government Organisation
GWC	Green Water Credit
IFAD	International Fund for Agricultural Development
INB	Incremental Net Benefit
IRR	Internal Rate of Return
ISRIC	World Soil Information
KenGen	Kenya Electricity Generation Company Ltd.
KFS	Kenya Forest Service
KTDA	Kenya Tea Development Agency
LH	Lower Highlands
LM	Lower Midlands
LTI	Long Term Investments
MKEPP	Mount Kenya East Pilot Project
MoA	Ministry of Agriculture
MoLD	Ministry of Livestock Development
NALEP	National Agriculture and Livestock Extension Programme
NGO	Non-Governmental Organisation
NPV	Net Present Value
NRM	Natural Resource Management
NUTMON	Monitoring nutrient flows and economic performance in African farming systems
PLWHA	People Living With HIV and Aids
SACCO	Savings and Credits Cooperative
SHG	Self-help group
SPSS	Statistical Package for Social Scientists
SWC	Soil and water conservation
UM	Upper Midlands
UTTA	Upper Tana Target Areas
WFP	World Food Programme
WRMA	Water Resources Management Authority
WRUA	Water Resource User Association
WOCAT	World Overview of Conservation Approaches and Technologies

Green Water Credits: the concepts

Green water, Blue water, and the GWC mechanism

Green water is moisture held in the soil. Green water flow refers to its return as vapour to the atmosphere through transpiration by plants or from the soil surface through evaporation. *Green water* normally represents the largest component of precipitation, and can only be used *in situ*. It is managed by farmers, foresters, and pasture or rangeland users.

Blue water includes surface runoff, groundwater, stream flow and ponded water that is used elsewhere - for domestic and stock supplies, irrigation, industrial and urban consumption. It also supports aquatic and wetland ecosystems. *Blue water* flow and resources, in quantity and quality, are closely determined by the management practices of upstream land users.



Green water management comprises effective soil and water conservation practices put in place by land users. These practices address sustainable water resource utilisation in a catchment, or a river basin. *Green water* management increases productive transpiration, reduces soil surface evaporation, controls runoff, encourages groundwater recharge and decreases flooding. It links water that falls on rainfed land, and is used there, to the water resources of rivers, lakes and groundwater: *green water* management aims to optimise the partitioning between *green* and *blue water* to generate benefits both for upstream land users and downstream consumers.

Green Water Credits (GWC) is a financial mechanism that supports upstream farmers to invest in improved green water management practices. To achieve this, a GWC fund needs to be created by downstream private and public water-use beneficiaries. Initially, public funds may be required to bridge the gap between investments upstream and the realisation of the benefits downstream.

The concept of green water and blue water was originally proposed by Malin Falkenmark as a tool to help in the understanding of different water flows and resources - and the partitioning between the two (see Falkenmark M 1995 Land-water linkages. FAO Land and Water Bulletin 15-16, FAO, Rome).

1 Introduction

1.1 Background

Green Water Credits (GWC) is an investment mechanism that will support rainfed smallholders to strengthen existing or to introduce improved *green water* management - these are all land, soil and water conservation (SWC) measures that will reduce runoff and enhance rainwater infiltration in farmers' fields, and reduce soil evaporation (see "GWC: the concepts" on page 12). The basic GWC concept is that when upstream farmers improve *green water* management, downstream water users will also benefit - from improved *blue water* resources, including regulated riverflow, reduced sediments in rivers and reservoirs and recharged groundwater resources. Downstream water users considered so far in GWC include: KenGen, Nairobi Water and Sewage Company and other large urban and industrial water users, irrigated estates (e.g. Del Monte and Kakuzi) and smallholder irrigators (e.g. Yatta irrigation scheme).

It is envisaged that the implementation of improved land and water management will be realised in two to three demonstration sub-catchments in the Upper Tana, each comprising an estimated 15,000 to 20,000 smallholder households. The selection of these demonstration sub-catchments will be based upon the Upper Tana Target Areas (UTTA) map (see Figure 1), which delineates hotspots. Implementation will take place under the forthcoming IFAD-funded Tana NRM Project, 2012-2019.

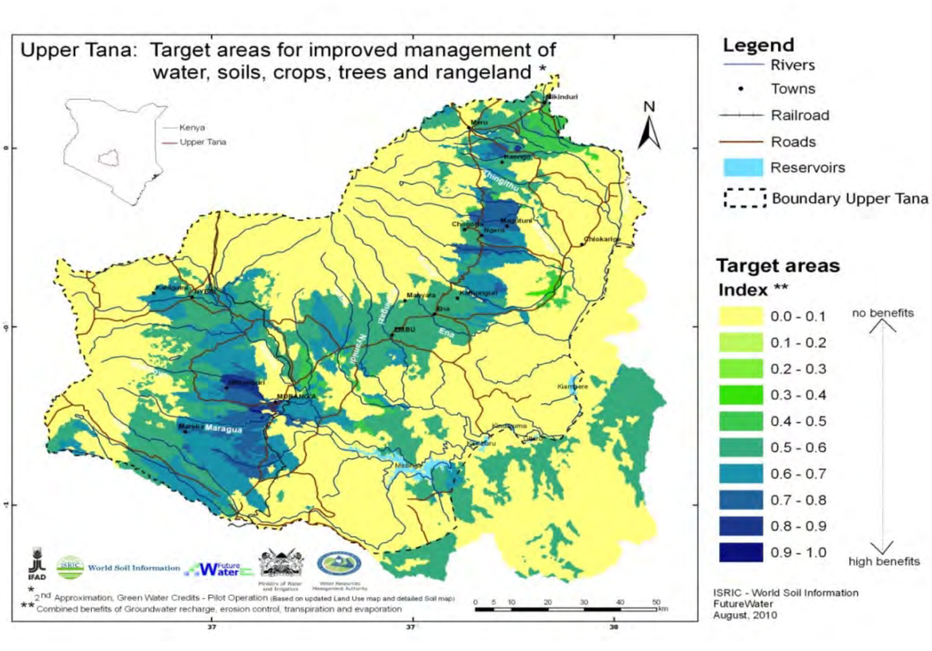


Figure 1
Map of Upper Tana river catchment. Source: GWC[1]

1 GWC 2010 Green Water Credit-Investment guidelines: http://www.greenwatercredits.net

To achieve the projected improved land and water management, the smallholder farmers will require short- and long-term investment packages. A short-term package represents the regular production inputs that the farmer needs - specifically seeds, fertilizers and agro-chemicals. The long-term investments form the backbone of the GWC concept and consist of the inputs that are required for improved soil and water management - labour, tools, mulching materials, cover crops, grasses for vegetative barriers, tree seedlings, etc. A portion of these long-term investments will be covered by the GWC investment fund and other environmental services grants, most probably in the form of soft loans, or grants in the form of vouchers.

The investment package should follow the principle of a "Commercial Sustainable Investment Package" (CSIP) as advocated by the Equity Bank. What is innovative in the CSIP is the "long-term investment" (LTI). The CSIP works well for regular farmers' loans that address seasonal inputs for recognised commodities such as tea, coffee, grains, livestock, etc. However, the challenge is to further develop the CSIP for a combined package that includes the long-term investments (LTI) inputs in soil and water conservation practices. In particular these investments in SWC, once introduced to many farmers, will lead to private and public benefits in: (i) on-farm productivity, (ii) ground water recharge, reduced flooding and reduced siltation of surface water, (iii) a sustainable protected soil and water natural resource base; and (iv) resilience to climate change. ETC East Africa was commissioned by ISRIC to carry out cost-benefit analyses for the development of a sustainable investment package and a GWC investment fund.

1.2 The study area

The study area comprised three selected sub-catchments in the Upper Tana GWC target area. The area was selected among the catchments identified as hotspots as far as land degradation is concerned. The selection was carried out in consultation with the Water Resources Management Authority (WRMA) Embu, and with the Mount Kenya Pilot Project (MKEPP). The selected sub-catchments were Kayahwe, a tributary of the Maragua river in Kahuro District; Lower Chania sub-catchment of the Chania river, (Gatundu North, Gatanga and Thika west Districts and parts of Nyandarua District) and Tungu sub-catchment a tributary of the Mutonga river in Meru South and Mara Districts. All the three sub-catchments selected have Water Resource User Associations (WRUAs) with sub-catchment management plans.

Figure 2
Kayahwe sub-catchment

Kayahwe sub-catchment, which is about 124 km^2 (see Figure 2), stretches from Kahuti in the north, extends southwards to Kaganda and is bounded by Kiruri to the west and Mukuyu to the east. It covers the following administrative districts: 80% of the sub-catchment is in Kahuro, 20% in Kangema and 15% in Kiharu. The sub-catchment straddles Murarandia, Mugoiri, Wangu, Kiharu and Kanyenyaini Divisions, covering seven locations. Kayahwe sub-catchment has an estimated population of 160,000. It has 4000 registered members with about 110 self-help groups.

Kayahwe sub-catchment is drained by the Kayahwe river, which has its source in Kiruri location within Kangema District. It flows downstream to Gaitega where it drains into the Maragua river covering an approximate distance of 65 km. Kayahwe river is served by many tributaries, namely Gaitango, Kanumira, Kaihungu, Muriuriu, Gicobo, Raini, Kahuaga, Kiriti, Kawarau, Tundumu, Thumara, Kambogo, Iria, Wariga, Kariara, and Itare. These tributaries form a dendritic drainage pattern. The sub-catchment also has several springs, wetlands, boreholes and dams.

The sub-catchment has three zones, namely Upper, Middle and Lower. In the Upper zone, tea, livestock farming and quarrying are practiced. In the Middle zone, coffee, horticulture, fish, livestock and subsistence farming are dominant, while in the Lower zone quarrying, horticulture, fish, livestock and subsistence farming are the most common practices.

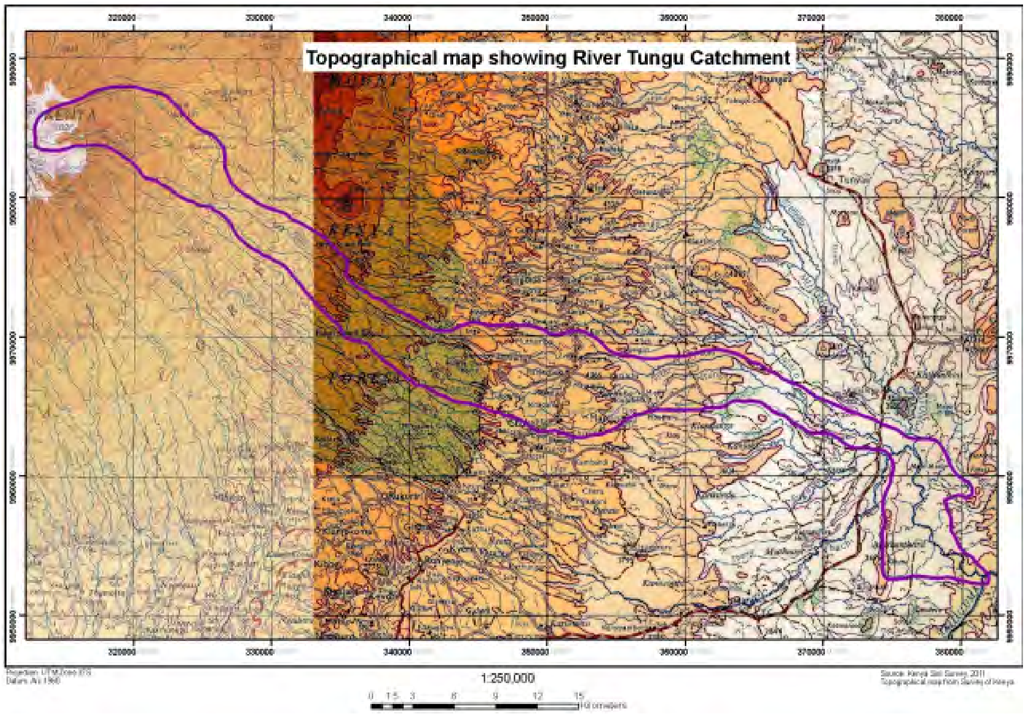


Figure 3
Tungu sub-catchment

Tungu sub-catchment, which is about 96 km^2 in extent (see Figure 3) falls under the Mutonga drainage area. The Tungu river originates from the forest of Mt Kenya and flows a distance of about 25 kilometres before its confluence with the Nithi river. It drains into the Nithi which later drains into the Mutonga. The Tungu has 37 tributaries and several springs. The main tributaries are: Thamia, Bwee, Mitheru, Kurugucha and Nkurumbaci. The sub-catchment has an estimated population of 60,000 within an area of approximately 111 km^2, giving a population density per km^2 of 530. The catchment is divided into five zones: forest, tea, coffee, tobacco/cotton and grazing.

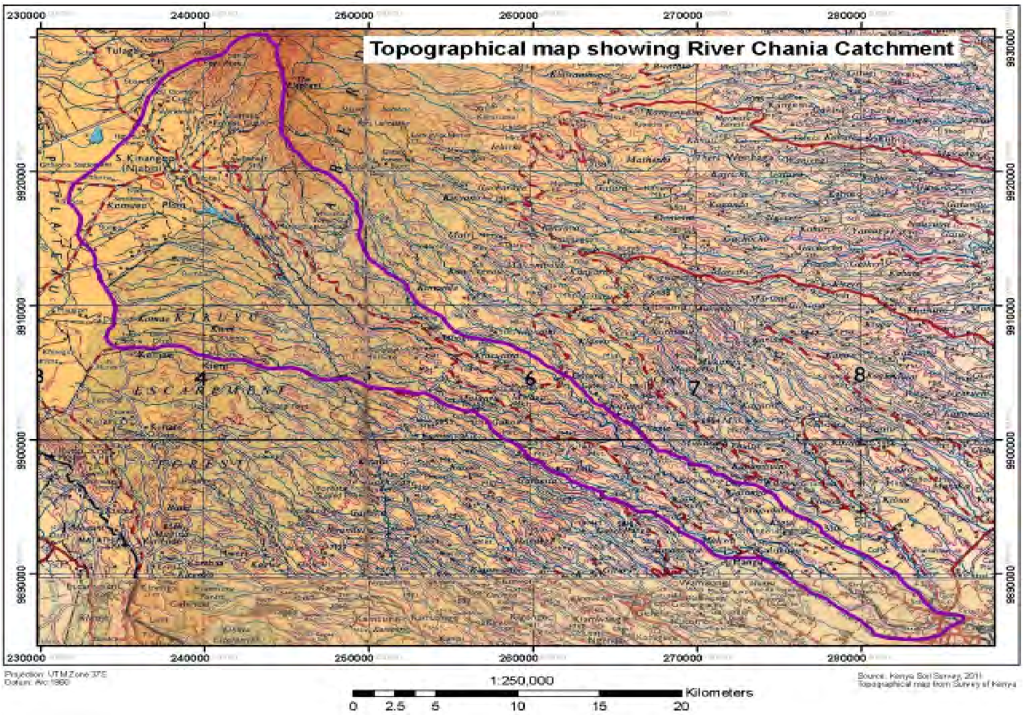


Figure 4
Lower Chania sub-catchment

Lower Chania sub-catchment is about 750 km^2 (see Figure 4) and stretches from the Kimakia /Kieni forests in the north extending southwards to the Blue Post Hotel in Thika bounded by the flyover of the Mang'u-Thika road to the west, and the Thika–Gatura-Kimakia road to the east. It covers the following administrative districts: 30% of the sub-catchment is in Gatanga, 60% in Gatundu north, 15% in Thika west and 2% in Nyandarua south. The sub-catchment straddles Mang'u, Chania, Kariara, Gatanga, Thamuru, south Kinangop and Thika Municipality Divisions covering 19 locations. The Lower Chania sub-catchment has an estimated population of 1,145,000.

Lower Chania sub-catchment is drained by the Chania river which enters the catchment at Ragia Location in Nyandarua South District flowing downstream to the confluence of the Thika and Chania rivers behind the Blue Post Hotel. It covers an approximate distance of 50 km. Lower Chania river is served by Kariminu, Nyakibai, Mataara and Kimakia tributaries, all forming a dendritic drainage pattern. Besides these main tributaries the sub-catchment encompasses several streams, springs, wetlands, boreholes, and dams.

1.3 Objective of the Study

The objectives of the study were:

- To conduct a field survey and carry out analyses of costs and benefits of selected soil and water conservation (SWC) or "*green water* management" measures relevant to smallholder farmers in each of the main agro-ecological zones in the selected sub-catchments within the Upper Tana area; and
- To conduct an off-site economic evaluation of hydrological benefits of improved SWC management measures.

Part I of this report is on on-site cost-benefit analysis of selected SWC measures. Part II of the report covers off-site benefits.

2 Approach and methodology

2.1 General approach and methodology

The study was conducted in four steps that were continuous - but discrete in terms of activities undertaken - in order to generate the expected outputs. These steps included (1) discussions with stakeholders, literature review and development of data collection tools; (2) developing the approach and methodology for the study; (3) field data collection; (4) data entry and analysis; and (5) report preparation. The approach and methodology used is described in detail below:

The on-site cost and benefits study was carried out in three sub-catchments in the Upper Tana area (as described in section 1.2). The sub-catchments were purposefully selected to include areas where soil erosion and land degradation were considered to be high and was simultaneously covered by a sub-catchment management plan under a water resource users association (WRUA). The sub-catchment was stratified into three elevation zones: Upper, Middle and Lower. In each zone, farm households that had undertaken the same SWC practices were purposefully sampled. Fourteen selected SWC practices were studied. For each farm-household the dominant SWC measure used was selected for documentation using a household questionnaire. Plots outside the sub-catchment were not included. A total of 433 households were interviewed (see Table 1). In addition, during fieldwork data regarding the prices of equipment and implements used for SWC was collected.

Table 1
Distribution of households studied

Agro-ecological zone	Sub-catchment			
	Lower Chania	Tungu	Kayahwe	Total
Tea-Dairy (LH1)	30	10	32	72
Tea-Coffee (UM1)	41	27	55	123
Main Coffee (UM2)	66	29	37	132
Marginal Coffee (UM3)	11	30	28	69
Cotton-Tobacco (LM3-cotton)	0	37	0	37
Total	148	133	152	433

LH=Lower Midlands; UM = Upper Midlands; LM =Lower midlands (Jaetzold *et al.* 2006a; 2006b)

Both qualitative and quantitative data were collected using a mix of study tools (household questionnaires, focus group discussions and key informant interviews). Two focus group discussions were held in the rangelands. Data collected were analysed using Ms Excel and SPSS where relevant.

2.2 Assumptions and approaches adopted during the cost-benefit analysis

2.2.1 **Background**

In cost-benefit analysis of SWC, the effects of continued erosion (or other types of soil degradation) on productivity are estimated for the time horizon of interest. The estimates are used to calculate returns at each point in time and the calculations are repeated under the conditions that would be experienced if a specific conservation measure was adopted. However, a finding that certain conservation practices are not profitable does not mean that no conservation measure is profitable - often, various measures designed to reduce degradation rates are already being practiced, implying that farmers consider them profitable (Demtew 2006).

In valuing the costs and benefits associated with implementation of SWC activities, different assumptions and choices were made at the beginning of the study. This study differs from others in that it analyses profitability of SWC measures based on data collected from actual farmers' practices.

Selection of soil and water conservation practices

Cost-benefit analysis involves identification of all components relevant, quantification of the items, and translating them into monetary terms. Soil and water conservation investment involves costs and benefits and this differs from one practice to another. Soil and water conservation practices targeted in the study were selected in collaboration with Green Water Credits Partners taking into account the existing knowledge about the Upper Tana. The SWC practices selected comprised structural and non-structural measures (Table 2).

Table 2
SWC technologies (Green water management measures) *selected for the study and number of households interviewed*

SWC Technology	Agro-ecological zone					
	Tea-Dairy (LH1)	Tea-Coffee (UM1)	Main Coffee (UM2)	Marginal Coffee (UM3)	Cotton-Tobacco (LM3-cotton)	Total
Bench terraces	6	20	16	4	0	46
Contour tillage + planting	2	3	9	2	1	17
Cut-off drains	3	4	8	10	0	25
Fanya juu terraces	8	27	39	13	4	91
Grass strips	12	14	15	13	7	61
Microcatchments for fruit trees (bananas)	5	10	11	5	2	33
Mulching	21	12	0	0	0	33
Retention/Infiltration ditches	5	15	15	7	0	42
Ridging	3	7	4	4	10	28
Riverine protection	6	6	9	3	0	24
Stone lines	0	0	1	1	5	7
Trash lines	1	1	3	4	7	16
Zero tillage	2	4	2	2	0	10
Total	74	123	132	68	36	433

Structural measures were defined as permanent features formed from earth, stone or masonry that are designed to protect the land from uncontrolled runoff, encourage infiltration into the soil and retain water where needed (Thomas *et al.* 1997; WOCAT 2007). Non-structural measures were defined as vegetative and agronomic measures that promote soil and water conservation through reduced runoff, encouraging infiltration and moisture retention, and reducing evaporation to the atmosphere. Contour tillage/planting and contour ridging were considered stand-alone practices without any stabiliser (grasses or otherwise).

2.2.2 **Investment and maintenance costs**

The costs that the farmer incurs in implementing SWC practices were classified as investment costs, since farmers expect to realise benefits from their SWC efforts, though often only in the long-term. In the analysis, two types of costs were identified: establishment costs (investment costs) and maintenance costs. All costs in the base year (base year = year 0) were regarded as establishment costs (Stocking and Abel 1992. Costs thereafter were taken as annual or maintenance costs.

The investment costs incurred in base year were (i) costs of laying out the SWC practices along the contours (ii) costs of construction and or establishment of the practices and (iii) costs of establishing stabiliser materials (e.g. grasses). Annual maintenance costs considered in the study include costs such as repairs/cleaning trenches (where relevant) and other costs such as gapping-up, fertilization, weeding, pruning, and application of trash as mulch.

2.2.3 Quantification and valuation of investment and maintenance inputs/costs

a) Labour

The amount of labour (in person-days) required to construct and maintain selected SWC practices vary with the length of the structure to be constructed and maintained on the area and the slope of the land. Labour inputs for soil conservation activities also differ with the type of conservation structures, availability of labour source and amount of labour payments. Labour requirement for constructing SWC measures was obtained by asking the farmer about a given length. In addition, some organisations working in the Upper Tana were interviewed to get an idea of labour costs for construction according to work standards. Aspects of labour investigated depended on the SWC structure in question but included labour for the following:

- laying out the structures and pegging them along the contour;
- excavation of trenches and microcatchment holes for physical/structural measures;
- applying mulch, trash lines and stone lines;
- planting stabiliser grasses, grass strips, tree seedlings and for carrying out tillage and ridging operations (land preparation, planting, fertilization etc.);
- application of herbicides under zero tillage; and
- maintenance of structures (repairs/cleaning trenches; gapping-up; fertilization; weeding; application of mulch and trash and prunings etc.).

The following assumptions were made:

- Farmers' own labour was valued at opportunity cost since a farm-labour market exists in the area. It was valued using the value of on-farm hired labour as an opportunity cost. Hired labour was valued at farm-gate rates as given by the farmer. This was in the range of KSh 150-200 per labour-day's work.
- Labour incurred in collecting material inputs for SWC was not directly valued due to high variability expected of such values from farm-to-farm and from one sub-catchment to another. Similarly, labour for fetching planting materials (napier grass splits, seeds etc) were not directly quantified. This appears a pitfall in this valuation considering that practices such as mulching, stone lines and trash lines may require considerable labour to collect the materials before the structures are made. In this study farmers were asked to estimate and include this labour aspect in the total labour required to apply mulch, stone lines and trash lines; and probably the eventual value used in the analysis may be an under-valuation in some cases.
- The value of on-farm hired labour (paid in cash) was considered for calculations and additional costs associated with farmers feeding of hired labourers were not considered due to high variability; in some households it is practiced, in others not. For this reason, unit labour costs considered for this study are understood to include "silent costs" of food gifts.
- The cost of laying out structures was calculated based on opportunity cost. In most places in the Upper Tana, it is the Ministry of Agriculture and/or Community Markers trained by Ministry of Agriculture and/or NGOs that lay out the structural measures and peg them out upon farmers' request but at no direct cash cost. In some parts of the catchment, the farmers do not make the structural measures along the contour due to inadequate skills, knowledge and or lack of tools (line level, levelling board etc.).

b) Tools and equipment

The construction of SWC structures requires tools and equipment. Farmers were asked about the type of tools and equipment they use in construction, their current prices (comparing these with market prices) and expected lifespan (and salvage value if any). Most frequently used tools for constructing SWC measures were included as a form of investment. Assumptions regarding the use of these tools were as follows:

(i) Structural measures: bench terraces, *fanya juu*, cut-off drains, retention ditches and microcatchments for bananas fork *jembes*, spade, *panga* and mattock (pick-axe) were considered in the calculations. It is noted that wheelbarrows are also used for transporting materials, but only 40% of the households in the three studied sub-catchments own them, and thus these were excluded from the analysis of investment costs. It was assumed that the labour costs also includes cost of tools since most hired labour come with their own and are paid by lump sum for work done. However, the farmers' own tools were included as a contingency in the calculations.

(ii) Non-structural measures: Trash lines, grass strips, contour tillage, ridging and riverine protection: *pangas* and *jembes* were considered in calculations. Interviews with farmers in the Upper Tana revealed that the majority of farmers use *pangas* and fork *jembes* in establishing these measures. The tools were included as contingencies for the reasons stated above.

2.2.4 **Quantifying and valuing benefits/outputs**

In this study, the benefits accruing from implementation of SWC structures were attributed to stabiliser grasses and trees grown on structure embankments and crops grown on the terrace beds. Information on quantities of harvested grasses, trees and tree products and crops grown were obtained by asking the farmers questions based on a specific conserved land area and then translating the same to a per-hectare basis. Outputs (harvests of grasses, tree and tree products etc.) 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, poles) and by-products (e.g. stover) were quantified. The inputs and factors of production were valued at their observed farm-gate prices while the farm household's own, non-purchased resources were valued at opportunity costs. Thus, not all the costs captured in this cost-benefit analysis are associated with an actual monetary expenditure for farmers. In quantifying benefits of SWC, the following assumptions and issues were taken into account:

a) Land and productivity loss due to conservation structures

The construction of structural soil conservation measures can result in a decrease in arable crop area. Previous studies on the profitability of conservation investment indicated that estimated area and value of cropland lost to conservation structures is difficult to assess due to the specific nature of the technology (Demtew 2006). Each conservation technology is suitable for specific conditions (such as slope, soil type, availability of stone), climate and farming system and land lost varies with slope.

In the literature, there are no standards to account for costs attributed to land and productivity loss associated with land taken up by SWC structures. Some authors propose that such costs need to be taken into account (Thomas *et al.* 1997; Ludi 2002) while others question the rationale for inclusion of such costs (eg Mwakubo *et al.* 2004). Assumptions made in this study are:

- Land and productivity is *not* lost when structural SWC measures are implemented. This is because SWC structures are a form of insurance facilitating crop diversification and providing a form of security to farmers in terms of stable yields. In practice, the area devoted to crop production is not entirely lost, since the edges/embankments of SWC structures are usually planted with fodder grasses, cover crops such as sweet potato vines or with fodder trees. Some farmers also plant bananas in the trenches. However, in the base year of SWC structure establishment, there will be no substantial yields and therefore, the yields are assumed zero (or "lost").
- Grass strips (e.g. napier grass) are assumed not to adversely affect the yields of crops grown close to it. In this study, actual crop yields were estimated by asking farmers who have napier strips, thus the effects of napier strips on crop production was captured *in situ* (i.e. yields reflect the "would have been" adverse effects of napier strips). However, some authors have postulated that the competition between napier grass strips and crops grown close to it (e.g. maize) may result in a reduction of crop yields as much as 10% (Thomas *et al.* 1997). However, other experiences have shown that napier strips to which *Desmodium* sp. is integrated helps in increasing maize yields ("push-pull" technology against stem borer) rather than

reducing it (Khan *et al.* 2008); and that the effects of grass strip establishment will eventually increase crop yields (and therefore counteract competition effects) due to reduced runoff and erosion and increased water infiltration and that crop yields will not necessarily reduce in the medium-term assuming such grass strips are well maintained and good agronomic practices are observed.

– SWC structures' useful lifespan are beyond the project term of seven years. Studies have shown that crop yields on terraces less than 10 years after construction are higher than yields from terraces that have been in existence for more than 10 years (Mwakubo *et al.* 2004) unless those terraces are well maintained annually. Other studies have indicated that the general lifespan of terraces is about 25 to 30 years, while farmers view the productive lifespan to be 15 years before re-investing again (Atampugre 2011). Other authors have reported that SWC measures such as stone lines and earth bench terraces have a lifespan of 10-20 years and 20-25 years respectively (de Graaf 1996). Grass strips and tree crops have a life span of 3-8 years and 10-50 years respectively. However, according to Mwakubo *et al.* (2004), the productive lifespan of terraces can be effectively infinite so long as they are well maintained annually. For this study, the productive lifespan is taken to be 15 years.

b) Estimating benefits of conservation

Soil and water conservation structures have a direct bearing on crop yields due to retention of soil moisture, nutrients, and prevention of seed loss. In cost-benefit analysis of SWC structures, the yields of crops (i) "before and after" the establishment of conservation structures (i.e. yields when erosion is taking place and yields when erosion has been controlled using SWC structures on the same farm); and (ii) the model of "with and without" SWC structures (latitudinal comparison) have been frequently used as a way of determining the beneficial effects of specific conservation measures. Both methods have their own strengths but suffer from various challenges in their attempts to estimate productivity loss (crop yields) attributed to erosion and the use of incremental yield gains in cost-benefit analysis framework. The first approach assumes an experimental situation with a temporal dimension where the effects of erosion on crop yields are measured before the construction of SWC structures and also after the construction of SWC in the same farm over a period of time; a costly venture. The second method measures the effects of soil erosion on crop yields by assuming that farms where SWC structures have been implemented ("with SWC" scenario) can be compared with farms where SWC structures have not been implemented ("without SWC" scenario) 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 by similar conditions. In reality this may not be the case as farm conditions, including soil factors, are rarely homogenous and farmers' socio-economic circumstances and level of management and slope factors vary even in the same farming zone.

In this study, the following assumptions were made:

– The effects of erosion damage was considered to be 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; Tenge *et al.* 2005).
– The benefits of SWC structures accrue from yields of grasses, fodder and trees planted on structure embankments and crops (annual crops and trees) planted within the conserved land and that the gross yield of crops includes yields of main products harvested (e.g. grain yields, fodder) but also the stover and other by-products (fuel wood from trees grown in conserved land etc.).
– The yield of crops lost in the "without scenario" 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 yield in a situation where there is no SWC measure is assumed to be 50% in the base year (i.e. the yields are lower by 50%), which falls within the brackets of the limited experimental data available. A

simulation study conducted on a steep slope in Kabete (Kenya) showed that a loss of 25 mm of soil results in a decline in maize yields by 50%. Studies carried out in parts of the Upper Tana (Embu District) on moderate to steep slopes (6-32%) with a loss of 0.4 to 0.68 cm (soil loss of 47-103 tonnes ha^{-1} yr^{-1}) resulted in 48-66% grain yield loss (Okoba 2005). Studies carried by Atampugre (2011) in the Upper Tana using the “with and without SWC situation” (latitudinal base comparison) have shown that maize yields are lower by 47% in farms without terraces compared to farms with SWC structures (on 20-40% slope).

  - For non-structural measures (trash lines, grass strips, contour tillage, ridging), it was assumed that maize and bean yields are low by 14% in farms without SWC structures at the base year. Results from field experiments in Kwalei, Tanzania show that bench terraces increases maize yields by 88%, *fanya juu* by 57% and grass strips by 14% against an average yield of 1250 kg ha^{-1} without a SWC measure (Tenge *et al.* 2005). The increase in bean yields due to soil conservation measures was 60% on bench terraces, 67% on *fanya juu* and 13% between grass strips against an average yield of 150 kg ha^{-1} on fields without SWC measure. The results are calculations based on a hectare per year.
  - Tea plots without mulch (of tea prunings) have 20% lower yields in the first year of production (year 5) than those mulched. Tea prunings added to tea as mulch significantly increased yields of both mature and young tea by 13–21% (De Costa and Surenthran 2005).
  - The non-use of microcatchments for banana production (no water harvesting and little or no manure application) leads to low yields (40% lower than those with the practice) in Kenya (Qaim 1999). Studies on banana yields due to non-use of microcatchments (water harvesting + manure application) are limited. However, Bekunda and Woomer (1996), in Uganda, have indicated that integrated use of organic sources of fertility (cattle manure, banana stalks and crop residues) in banana fields results in 42% to 57% higher banana yields than low and single application of banana stalks alone, banana stalks with crop residues alone, and or single low application of small quantities of small stock manure/compost. In a study of banana production in Kenya, better managed banana fields (medium- to large-scale non-tissue culture banana production) experienced 35%-74% higher yields than poorly managed small-scale fields (Qaim 1999). For tissue culture bananas, the yield increase was 34% higher in better managed banana fields than in poorly managed fields (small-scale production). Farmers growing tissue culture bananas and or grow bananas on medium-to-large scale usually practice water harvesting techniques (microcatchments).
  - Yields of crops were extrapolated to one hectare of land for comparison purposes although some of the smallholders own less than one hectare of land. This appears justified since little mechanisation is used in the study sites and thus the economies-of-scale are more or less negligible.
- Crop yields in farms without SWC measures (ie without *green water* management measures) are assumed to decline (due to erosion) linearly by a percentage of the previous year’s yields:
  1. Maize and other grain crops (sorghum, beans) by 2%; coffee, 2% and tea, 1% (Atampugre 2011). Data on annual yield decline due to erosion is limited and the limited data available have varying estimates with some authors postulating that a decline by a small percentage e.g. 2% yield decline per year is plausible (de Graaff 1996). Studies carried out by FAO (1986) revealed annual yield decline of 1.8% at soil losses of 100 t/ha; Hurni (1988) reports annual yield decline of 2% at soil losses of 42 tonnes ha^{-1} yr^{-1} while Kappel (1996) reports 0.12 to 2% yield decline at soil losses of 10 to 35 tonnes ha^{-1} yr^{-1} in Ethiopia.
  2. The relative decline in yields for beans was assumed to be equal to that of maize due to limited availability of data. In reality beans provide a better cover crop than maize; In most situations in the Upper Tana, maize is intercropped with beans (and other pulses e.g. cowpeas), although the interactions between maize-beans in reducing erosion were not taken into account in this study.
- Crop yields in farms with SWC measures (ie with *green water* management measures) are assumed stable and remain constant. Bojö (1991) in his study in Lesotho, assumes that yields remain constant on land with terracing and drains, whereas on land without conservation yields decline at a rate of 1% of the previous year’s yields. However, in reality the yield may increase initially after the construction of SWC practices

before being stable. Wiggins and Palma (1980) found that, in the absence of soil conservation structure, maize yields decline at a rate of 2% per centimetre loss of topsoil and that the initial increase in yields arising from implementation of conservation measures was 10%.
– The benefits of conservation structures were considered to deliver high gross margins as a result of increased crop yields and ease of operations.

2.2.5 **Determining discount rate and time horizon**

Benefits of investments into SWC made now are mainly realised in the long-term, thus there is unfavourable distribution of costs and benefits over time. A benefit obtained in the future is not as valuable as the same benefit obtained today. A cost-benefit analysis takes this fact into account by using a discount factor (rate) to reduce the value of the future net benefit and show its present value. Discount rate chosen affects the magnitude of streams of benefits realised and the time it will take for farmers to have positive returns on their investments on SWC. It has little effect on the value of immediate costs and benefits but the greater the value of the discount rate, the smaller the impact of long-term costs and benefits on the result of the analysis (Stiglitz 1994).

The focus of the study is on analysing costs and benefits of SWC practices based on data collected from smallholder farmers. Thus, the appropriate discount rate to use should be the interest rate payable by the farmer at an appropriate bank loan. Discount rates should reflect time preference of rural households on the one hand and opportunity costs of capital on the other hand. However, in the literature, the discount rate commonly used for the evaluation of SWC projects is 10% for a 5-50 year time period. In the Kenyan environment, interest rates offered by various financial institutions to smallholders ranged from 12% to 14% in the period of the study against Central Bank bench rates of 8-8.5%. In the study 12% was used as the discount rate while 10% and 14% rates were used for comparison purposes and for sensitivity analysis.

Since the stream of benefits derived from structural SWC are realised in the long-term, the most practical way of comparing costs and benefits is to estimate costs incurred for implementing SWC and the extra income arising from conservation, on a year by a year basis over a selected time period (the time horizon). When the time horizon is short, the viability of SWC measures may become questionable and when a longer time horizon is selected, the benefits can be weighed accordingly. However, smallholders plan their activities over a shorter time period, given the insecure environment and risks they are faced with and there is a drive to use all the available resources for current consumption to secure survival (Kappel 1996). Therefore this study assumes a medium time horizon and postulates that the SWC activities studied will provide returns within 5-10 years. The time horizon selected for this analysis is 15 years based on the perceived lifespan given by the farmers before re-investing in the structure again.

2.2.6 **Decision criteria**

The profitability of the practices was determined using financial Cost-Benefit Analysis method. The Cost-Benefit Analysis framework compares cost and benefits figures over the lifespan of conservation practice and then computes the present value of the net benefit stream at the prevailing discount rate (Francisco 1998). In this study (i) Net Present Value (NPV) (ii) Internal Rate of Return (IRR) (iii) Benefit-cost Ratio (BCR) and (iv) Incremental Net Benefits (INB) were adopted as the decision criteria of determining the viability/worth of the studied SWC practices. These concepts, their associated formulae and how they are applied to the current study are presented in Annex 1.

3 Findings

This chapter presents the findings of the study. The findings are presented in six sub-sections as follows:
– Section 3.1: Household characteristics and general demographic information
– Section 3.2: Farming system characteristics
– Section 3.3: Investments in SWC measures with perennial crops
– Section 3.4: Investments in structural SWC measures with annual crops
– Section 3.5: Investments in agronomic and vegetative SWC measures with annual crops
– Section 3.6: Focus group discussions on conservation of rangeland areas

3.1 Household characteristics and general demographic information

This section provides the findings of the study obtained from 433 household interviews, two focus group discussions and key informant interviews. It provides the general characteristics of the households and respondents interviewed.

3.1.1 Population structure

The total number of households interviewed was 433. The total number of inhabitants of these households (population) was 2612 persons (1337 males and 1275 females). The sampled population was almost of equal sex distribution with 51% males and 49% females. This implies that both men and women need to be targeted. The structure of the population in the households studied is shown in Table 2. The majority of the population (both males and females) in all the three sub-catchments falls under the category of age 16-59. This is the productive age bracket which can offer labour at farm level.

Table 3
Population distribution of the studied households

Age and gender	Sub-catchment			
	Lower Chania	Tungu	Kayahwe	Total
Males > 60 yrs	27	35	55	117
Females > 60 yrs	24	26	39	89
Males 16-59 yrs	323	244	309	876
Females 16-59 yrs	315	267	314	896
Males 5-15 yrs	78	114	67	259
Females 5-15 yrs	86	82	46	214
Males < 5 yrs	33	31	21	85
Females < 5 yrs	35	26	15	76

3.1.2 Household head characteristics

The age of household heads in Lower Chania and Tungu sub-catchment ranges from 20-24 years to over 80 years while in Kayahwe sub-catchment it ranges from 25-29 and over 80 years. The population distribution data of the household heads shows that 41% of them are above age 60 years while 59% are between ages 20 and 59 years.

In Lower Chania sub-catchment 88.5% of the households interviewed are male-headed while in Tungu and Kayahwe sub-catchments the male-headed households are 81 and 88% respectively. This implies that the household headship is male-dominated and the decision-making is also likely to be male-dominated. This implies that it is important to include men in the GWC *green water* management (SWC) interventions.

The main occupation of the household heads is farming on family fields (77% of the respondents) while about 12% are involved in off-farm employment in farming activities and 11% in other off-farm employment. About 88% of the household heads are married.

About 85% of the household heads interviewed are literate. The majority of the male-headed households reported that the respondents had at least 8-9 years of education while the female-headed households had 5-6 years of education.

About 49% of the household heads reported that they were involved in off-farm activities while the rest were not. 22% of the household heads reported to be receiving remittances while 78% were not.

3.2 Farming system characteristics

This section describes the land characteristics and ownership, the type of cropping systems and livestock kept in the study area. It also describes the type of soil and water conservation being used and the type of equipment and assets for SWC practices.

3.2.1 Land characteristics and ownership

Land in the study area is either held under individual tenure (freehold ownership) where land adjudication has been completed or as trust land. Land in the Upper, Middle and Lower parts of the three sub-catchments studied have been adjudicated and land is held under individual tenure. However, in the lower parts of Tungu sub-catchment and the rangelands (where focus group discussions were held) the land has not been adjudicated and is held “under trust” by county councils on behalf of local communities until such time that the land may be sub-divided into individual holdings.

The per-capita land area in the study area, particularly in the Upper and Middle reaches of the sub-catchments, has been declining due to increase in population and land fragmentation. The land holdings are variable in the various agro-ecological zones in the three sub-catchments studied (see Tables 4a, 4b and 4c).

Table 4a
Land holdings in Lower Chania sub-catchment

Agro-ecological zone	Area O+M (ha)		Area O-M (ha)	
	Mean	Standard Deviation	Mean	Standard Deviation
Tea-Dairy (LH1)	1.34	1.28	0.06	0.3
Tea-Coffee (UM1)	0.84	0.84	.00	.00
Main Coffee (UM2)	0.60	0.71	.00	.01
Marginal Coffee (UM3)	0.86	0.35	.00	.00
Total	0.84	0.91	.01	.14

O+M = Owned and Managed; O-M= Owned but not managed (rented out).

The mean land holdings of the households studied in Lower Chania sub-catchment vary from 1.34 hectares in the Tea-Dairy zone (LH1) to 0.6 hectares in the main coffee zone (UM2)-Table 4a. It should be noted that in the lower parts of the Lower Chania sub-catchment there are large-scale coffee farms which have large land holdings but these were not included in the study.

The mean land holdings of the households studied in Tungu sub-catchment vary from 1.03 hectares in the Tea-Dairy zone (LH1) to 0.62 hectares in the Tea-Coffee zone (UM1)-Table 4b. In the Kayahwe sub-catchment holdings vary from 1.07 hectares in the Tea-Dairy zone (LH1) to 0.94 hectares in the Tea-Coffee zone (UM1) - Table 4c.

Table 4b
Land holdings in Tungu sub-catchment

Agro-ecological zone	Area O+M (ha)		Area O-M (ha)	
	Mean	Standard Deviation	Mean	Standard Deviation
Tea-Dairy (LH1)	1.03	1.33	.00	.00
Tea-Coffee (UM1)	0.62	0.43	.00	.00
Main Coffee (UM2)	1.03	0.86	.01	.08
Marginal Coffee (UM3)	0.97	0.89	.07	.27
Cotton-tobacco (LM3-cotton)	0.84	0.74	.12	0.68
Total	0.88	0.82	.05	0.37

O+M = Owned and Managed; O-M= Owned but not managed (rented out).

Table 4c
Land holdings in Kayahwe sub-catchment

Agro-ecological zone	Area O+M (ha)		Area O-M (ha)	
	Mean	Standard Deviation	Mean	Standard Deviation
Tea-Dairy (LH1)	1.07	1.11	0.11	.30
Tea-Coffee (UM1)	0.94	0.73	0.05	.19
Main Coffee (UM2)	0.99	0.83	0.11	0.51
Marginal Coffee (UM3)	1.06	0.78	0.00	.00
Total	1.00	0.85	0.07	.31

O+M = Owned and Managed; O-M= Owned but not managed (rented out).

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%). The steepest slopes are found in farms in the Tea-Dairy zone followed by farms in the Tea-Coffee and Main Coffee zones (Table 5). This makes the farms in these areas very susceptible to soil erosion if no SWC measures are put in place. In addition to the steepness of slope, the inherent erodibility of soil type is also very important erosion determining factor. In the Upper Tana catchment generally the Lower High and the Upper Middle zones have erosion resistant soils, while Lower Middle zones have soil types that are more sensitive to erosion as well. However, the most determining factor is surface cover by crops and vegetation. Unprotected bare soil due to land use is the most critical factor.

Table 5
Percentage distribution of households by slope of farms studied

Agro-ecological zone	Household distribution (%)			
	Gentle to moderate (<25%)	Steep slope (26-55%)	Very steep slope (>55%)	Total
Tea-Dairy (LH1)	25.0	63.9	11.1	100.0
Tea-Coffee (UM1)	34.1	61.8	4.1	100.0
Main Coffee (UM2)	40.2	53.8	6.1	100.0
Marginal Coffee (UM3)	50.7	43.5	5.8	100.0
Cotton-tobacco (LM3-cotton)	73.0	27.0	0.0	100.0
Total	40.4	53.8	5.8	100.0

3.2.2 **Crops grown**

Rainfed agriculture is the major livelihood activity in the study area. It is practiced in two rainfall seasons: the “long rains” (March to June) and the “short rains” (October to December). The rainfall varies with altitude with the most in the upper reaches with high altitude (>1600 mm per annum) to the lowest in the rangelands (about 500 mm per annum). Small-scale irrigation is also practiced throughout the agro-ecological zones.

There is intensive rainfed farming in the upper reaches of the sub-catchments. The cash crops grown include tea, coffee and fruit trees including mangoes, macadamia and avocado. Most of the respondents reported that they grow bananas, maize, beans, sweet potatoes and vegetables (kale, spinach and peas). The farmers in the

Cotton–Tobacco zones in Tungu sub-catchment grow tobacco and sunflower as cash crops and subsistence crops including sorghum, pigeon peas, green grams, *lablab* bean (*Dolichos lablab*) and cassava. Out of the 433 households interviewed 294 (68%) were growing bananas, 215 (50%) were growing beans and 172 (40%) were growing maize under conserved land.

About 27.7% respondents in Lower Chania sub-catchment, 11.3% in Tungu sub-catchment and 17.1% in Kayahwe sub-catchment reported practicing small-scale irrigation. The dominant crops grown under irrigation include beans, maize, tomatoes, cabbages, onions, sweet pepper and kales. The number of households growing irrigated crops in conserved land was small and the percentage of the area under irrigation was Lower Chania (14%), Tungu (10%) and Kayahwe (10%).

3.2.3 **Livestock production**

Most of the respondents interviewed in all sub-catchments reported that they keep livestock. The common livestock kept are cattle, goats, sheep and poultry. A few households reported keeping pigs and rabbits. Manure from all the livestock is used in the farms. Cattle consume feed (mainly napier grass and other grasses) grown in conserved lands – especially grasses grown on the structures for stabilisation. In addition cattle provide draft power.

3.2.4 **Soil and water conservation practices**

Adoption of SWC practices

The adoption of soil and water conservation practices by the households interviewed is shown in Table 6. From the table it is apparent that the dominant soil and water conservation practice adopted is *fanya juu* terracing (52.6%), followed by grass strips (35.3%), bench terraces (29.1%), retention ditches (17.2%), planting trees (12.3%) banana microcatchments (11.9%) and cut-off drains (10.5%). Other SWC practices adopted include ridging, contour tillage, riverine protection, trash lines, stone lines, cover crop, zero tillage, *zai* pits among others (see Table 6).

Inputs used in establishing SWC practices

The frequently mentioned inputs used for establishing SWC practices (structural and non-structural measures) include labour; implements (fork *jembe*, *panga*, hoe, spade, axe, wheel barrow, mattock, pruning knife, file, levelling board and spirit level); materials (napier grass, trash materials, mulch materials, stones, stabiliser planting materials-seeds, seedlings cuttings; herbicides) and other materials such as strings and pegs. Almost the same inputs, equipment and materials were cited as inputs required for maintenance of the physical SWC structures. For the non-physical structures the mentioned inputs for maintaining the structures included napier (42.1%), stabiliser planting materials (17.8%), mulch (8.6%), stones and cover crops (5.6% each), fertilizer and trash materials (4.1% each) and herbicides (1.5%). The proportion of inputs required varied according to agro-ecological zones. For example stones were common in the drier zones and the rangelands while the planting materials like napier grass was popular in the higher rainfall areas.

Table 6
Adoption of SWC practices by sub-catchment (% of households by sub-catchment)

Grouping	SWC practice	Sub-catchment			
		Lower Chania	Tungu	Kayahwe	Total
A	Manure use	0.0	11.4	0.0	3.5
A	Mulching	19.2	5.3	3.3	9.3
A	Ridging	1.4	9.1	7.9	6.0
A	Agroforestry	0.7	2.3	0.0	0.9
A	Contour tillage + Planting	2.1	1.5	13.8	6.0
A	Zero tillage	2.1	0.8	3.3	2.1
M	Fallow land (with grass)	1.4	1.5	0.7	1.2
M	Crop rotation	0.0	9.1	0.0	2.8
S	Bench terrace	30.1	15.9	39.5	29.1
S	Cut-off drain	10.3	15.9	5.9	10.5
S	*Fanya juu*	58.2	65.9	35.5	52.6
S	Retention ditch (*Fanya chini*)	14.4	13.6	23.0	17.2
S	Stone lines	0.0	7.6	0.0	2.3
S	Runoff pits	0.0	1.5	0.0	0.5
A or S	Banana microcatchment	13.0	10.6	11.8	11.9
A or S	*Zaï* pits	0.0	1.5	0.0	0.5
V	Grass strips	37.7	43.2	26.3	35.3
V	napier	4.8	1.5	3.9	3.5
V	Sweet potatoes	0.0	0.8	0.7	0.5
V	Pasture grass establishment	0.7	0.0	0.0	0.2
V	Planting trees	20.5	15.2	2.0	12.3
V	Cover crop (unspecified)	0.0	3.8	0.0	1.2
V	Grass cover	2.1	3.8	5.3	3.7
V	Riverine protection	7.5	3.8	4.6	5.3
V	Hedges	0.0	1.5	0.0	0.5
V	Trash lines	2.7	12.9	2.6	5.8
V	Woodlot	2.1	0.0	0.0	0.7
V	Tea cover	2.1	3.0	0.0	1.6
	Total	100.0	100.0	100.0	100.0

A= Agronomic measure; M= Management measure; S = Structural Measure; V = Vegetative measure

Farmers perceived benefits of soil and water conservation practices

From farmers' responses the frequently perceived benefits derived from SWC practices were (percentage of households in parenthesis):

- Conservation of soil/reduction of erosion (24.3%)
- Source of fodder (22.9%)
- Increase in crop production (16.8%)
- Improvement/maintenance of soil fertility (9.2%)
- Conservation/retention of moisture (14.8%)
- Source of income from sale of fodder, timber, crops etc. (3.2%)
- Control of run-off and increase infiltration (1.7%)
- Water harvesting for crop production (1.2%)
- Provision of fuel wood, timber and poles (1.2%)
- Stabilisation of riverbanks (0.2%)

3.2.5 **Equipment and assets for SWC practices**

From responses received most of the farmers have major tools/equipment (such as hoes, fork *jembes*, spades, *panga* and axes) needed for constructing SWC measures (see Table 7). However, most of them do not have equipment like wheelbarrow, rakes, ox-plough, watering cans, knapsacks, hand sprayers and forks.

Table 7
Number of households owning assets for SWC

Tool/Equipment	Sub-catchment				
	Lower Chania	Tungu	Kayahwe	Total	Percentage of total
Hoe	135	64	142	341	79.8
Fork *jembe*	135	129	145	409	94.5
Spade	137	120	137	394	91.0
Panga	137	129	150	416	96.1
Axe	106	91	129	326	75.2
Rake	35	23	45	103	23.8
Wheelbarrow	75	57	75	207	47.8
Ox-plough	0	5	0	5	1.2
Watering can	50	40	33	123	28.4
15-litre Knapsack sprayer	33	21	14	68	15.7
20-litre Knapsack sprayer	27	20	16	63	14.5
10-litre Knapsack sprayer	4	2	0	6	1.4
Hand Sprayer (others)	11	16	0	27	6.2
Fork	8	4	0	12	2.8

3.2.6 **Farm labour resources for SWC practices**

The number of households managing the work of SWC alone is shown in Tables 8a (Lower Chania and Tungu Sub-catchments) and 8b in Kayahwe sub-catchment. From the tables only 40.7% and 18.8% households in Lower Chania and Tungu respectively reported that they do the SWC practices alone while in Kayahwe sub-catchment about 61.3% of the households do the SWC practices alone. This implies that in almost all sub-catchments the farmers hire labour to assist them in construction of SWC practices but this is more so in Tungu and Lower Chania sub-catchments. This cuts across all the agro-ecological zones.

Table 8a

Households managing the work of SWC alone (% of total households by agro-ecological zone)

Agro-ecological zone	Lower Chania	Tungu	Kayahwe	All
Tea-Dairy (LH1)	46.7	0.0	71.4	52.3
Tea-Coffee (UM1)	36.1	27.8	53.1	42.7
Main Coffee (UM2)	44.8	37.5	73.0	54.4
Marginal Coffee (UM3)	18.2	0.0	50.0	30.2
Cotton-tobacco (LM3-cotton)	0.0	23.5	0.0	23.5
Total	40.7	18.8	61.3	45.2

The reasons for the households not managing to carry out SWC practices alone are given in Table 9. Most of the respondents (47.0%) indicated that they do not have adequate family members to offer labour (Lower Chania - 64.5%, Tungu - 44.6% and Kayahwe - 29.2%). Most of the respondents in Kayahwe (43.8%) reported that they lack finances to hire labour followed by those in Tungu (25.0%). The other reasons given are: some family members have migrated to other places in search of off-farm employment, some family members are sick and weak and some farmers work for other people and have insufficient time to work in their own farm (see Table 9).

Table 9

Percentage distribution of households by reasons advanced for not managing SWC alone

	Sub-catchment			
	Lower Chania	Tungu	Kayahwe	Total
Inadequate family members to offer labour	64.5	44.6	29.2	47.0
Lack of finance to hire labour	4.8	25.0	43.8	23.3
Work for other people and have insufficient time to work in my own farm	4.8	2.2	6.3	4.0
Part of family members have migrated to other places in search for off-farm employment	21.0	17.4	15.6	18.1
Some of the family members are sick and weak	4.8	10.9	5.2	7.7
Total	100.0	100.0	100.0	100.0

The most frequently used strategies for addressing labour shortages for SWC practices were as follows (percentage of total households in brackets):

- Through labour work parties (13.2%)
- Hiring casual labour in times of need (41.4%)
- Support from relatives in peak periods (10.3%)
- Hiring permanent/resident labour (5.5%)
- Use of hired traction (animal draft power (1.2%)
- Use hired traction (machinery-tractor) (14.8%)
- Implementation in small portion of the field each season until the whole farm is covered (11.7%)
- Planting high value crops (1.9%)

3.2.7 **Farmer organisations and networking**

In most parts of the Upper Tana catchment farmers are organised into either self-help groups (SHGs), community based organisations (CBOs), faith based organisations (FBOs), SACCOs, youth groups, village associations and others (associations and networks). However, the majority of the farmers are in SHGs (20%) followed by FBOs (16%), Figure 5.

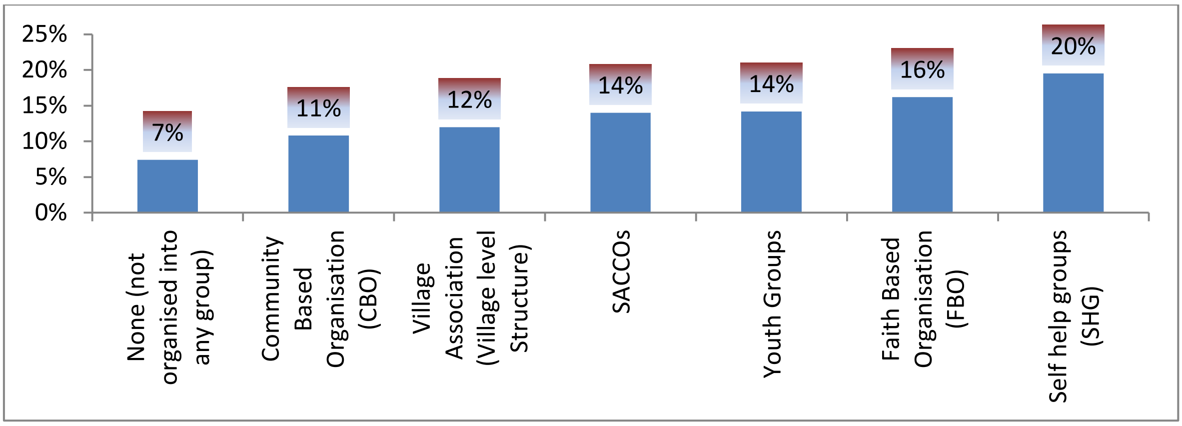


Figure 5
Organisations: percentage of households belonging to grouped categories

When respondents were asked to rank the service providers they did so them as shown in Table 10. Ranking was carried out based on categories of organisation rather than by individual names of organisation to “preserve” objectivity. The government organisations (GOs) were ranked as the highest service provider followed by FBOs and self-help groups and SACCOs. NGOs, CBOs and private sector organisations were ranked equally at number four service providers. Scoring and ranking was done on a scale of 1-6 with 1 being the highest rank.

Table 10
Mean scores and rank of service providers by respondents in Upper Tana catchment

	Mean score	Rank
Government bodies (GOs)	2	1
Non-governmental organisation (NGOs)	4	4
Community based organisation (CBOs)	4	4
Self-help groups and SACCOs	3	2
Faith based organisation (FBO)	3	2
Private sector organisation	4	4

During focus group discussions with Nkuuni/Kithukioni food-for-asset (FFA) group in Kamanyaki location, Tharaka south Division in the rangelands the participants identified the following service providers in their area:
- Catholic Diocese of Meru (FBO);

– Government organisations: Mount Kenya East Pilot Project (MKEPP), Ministry of Agriculture (MoA), Ministry of Livestock Development (MoLD) and Kenya Forest Service (KFS)
– World Food Programme (WFP)
– People Living with HIV and AIDS (PLWHA)

Using pairwise ranking the group ranked the service providers as follows:
1. Catholic Diocese
2. MoA , MoLD, MKEPP, and WFP
3. PLWHA
4. KFS

Similarly during the focus group discussions with farmers in Nthigirani Village, Kamarandi Location, Evurore Division, Mbeere North District in the rangelands the participants identified service providers and using pairwise ranking they ranked them as follows:
1. MKEPP
2. MoA and MoLD
3. Catholic Diocese
4. Care International

3.3 Investment in SWC measures with perennial crops

3.3.1 **Microcatchments with bananas**

a) Description of practice

Bananas are an important horticultural crop in terms of their present and potential contribution to food and nutritional security and income enhancement for smallholder farmers who are the predominant growers in the Upper Tana catchment of Kenya. It is estimated that 98% of banana growers in Kenya are small-to-medium scale in nature (AHBFI 2008). Banana is grown across all the agro-ecological zones studied in the Upper Tana catchment and both local varieties and tissue culture bananas are found in the catchment, with the former being rampant.

Bananas are grown in planting holes (0.6 metres wide x 0.6 metres deep)[2] to which farmyard manure is mixed with top soil (excavated from the hole) and returned to the hole (not filled to the brim). The scooped sub-soil from the planting hole is used in making a bund around the planting hole to trap water (microcatchment for banana planting). The microcatchment (planting hole) traps rainwater, retains moisture and concentrates nutrients for banana production and minimises runoff. The spacing of banana varieties was obtained by asking the farmer (average 3 x 3 metres). Other studies have indicated that this spacing can be up to 5 x 4 metres under intercrop systems with a single stool having 10-15 stems at a time (Qaim 1999). The bananas were predominantly grown under rainfed conditions. The microcatchment for banana production was compared with a situation “without” scenario where farmers prepare planting holes, but fills it to the brim with soil and do not make bunds around the hole, and or control soil erosion and trap runoff. Banana is a perennial crop associated with investment costs at time of establishment and also annual maintenance costs.

[2] In the lower parts of the catchment, the banana planting holes are larger: 90-120 cm diameter x 60 cm deep.

b) Investment costs of microcatchment with bananas

The investment costs of growing bananas were derived as arithmetic mean values of the figures reported by the 33 households interviewed. Not all costs presented are cash costs (Table 11). Banana planting material (suckers) taken from farmer's own banana plants were valued at the opportunity costs given by the farmer (KSh 20-40 per piece) while purchased suckers were valued at farm gate prices as given by the farmer (KSh 50-100 per piece). Family labour was valued at opportunity cost while inputs where farmers spent cash were valued at "cash cost prices" as given by the farmers. The average labour demand for establishment of banana microcatchments was 297 labour-days ha^{-1}.

Table 11

Investments costs of microcatchment with bananas-one hectare (n = 33)

Description	Quantity	Unit	Unit price	Total value KSh/ha
Labour land preparation	30	Day	150	4500
Labour for hole digging	1111	Number	30	33,330
Manure	1111	Wheelbarrow	50	55,550
Labour for manure application	22	Day	150	3300
Nematicides (Mocap)	33	Kg	80	2640
Banana suckers/planting material	1111	Number	80	88,880
Labour for planting	23	Day	150	3450
Total				191,650

Note: 1 US$ = KSh 88 at time of the study.

Tools and equipment required for banana establishment include fork *jembe*, spade, *panga* and in some areas pick-axe. According to farmers' estimates on the number of tools required of each type, a total of KSh 5500 ha^{-1} would be required to purchase tools for establishing banana microcatchments. This brings the total costs of establishment to KSh 197,150 ha^{-1}.

c) Maintenance costs of microcatchment with bananas

A similar valuation methodology was used as with the investment costs. Maintenance costs comprised manure application, weeding, harvesting and handling and other costs (pruning and de-suckering and propping of banana pseudo-stems), Table 12. Mulching (even with chopped pseudo-stems) and inorganic fertilizer application were not observed among the farmers interviewed. De-suckering is also not regularly practiced among smallholder farmers (Qaim 1999). The average annual labour demand for maintenance of the practice was 81 labour-days ha^{-1}.

Table 12
Annual maintenance costs of microcatchment with bananas-one hectare

Description	Quantity	Unit	Unit price	Total value (KSh/ha)
Manure application	555	Wheelbarrow	50	27,750
Labour manure application	22	Day	150	3300
Weeding	27	Day	150	4050
Other costs	15	Day	150	2250
Harvesting and handling	17	Day	150	2550
Total				39,900

Note: 1 US$ = KSh 88 at time of the study.

d) Quantifying benefits

The benefits of microcatchments with bananas were quantified by asking the farmer about yields over the last year. The yields of bananas comprised harvested banana bunches and pseudo-stems. Banana pseudo-stems are used in livestock feeding while banana bunches are either sold or used at home as food. The pseudo-stems were valued at either the price that farmers purchase them and or at opportunity cost as given by the farmer.

Once established, the local banana varieties take about 18 months to fruiting (time between planting and first crop harvest) while the improved ones take about 9-12 months for the first crop to be harvested (KARI 1998). In this study, most of the bananas planted were local varieties - in contrast to tissue culture (TC) bananas, which has an income flow generated in the first year. The average banana stool/plantation replacement is 14 years (one cycle), although this figure hides the fact that many banana stools at farm level could be as old as 40 years (Qaim 1999). Other authors have reported that banana field/plantation can last as long as 50 years (Bekunda 1999). Studies on banana yield decline due to non-use of microcatchments (water harvesting + manure application) are limited. In this study, it was assumed that the non-use of microcatchments for banana production and or growing bananas in field experiencing erosion will lower yields by 40% (at the start year of banana production) and thereafter there will be a linear yield decline of 11%.

Banana yields usually show a yield peak in the first and second ratoon (second to fourth year) before declining in subsequent years. Banana yields have been observed to decline annually by a factor of 0.05 for TC bananas (usually grown using microcatchments) and by a factor of 0.11 for non-TC bananas (usually grown without proper microcatchments) from peak yield period in year 3-4 to year 14 (Qaim 1999). Thus, cost-benefit analysis calculations based on a single year cannot capture fully the time dependent costs and benefit streams of banana cycle. In this study, a time horizon of 15 years was considered in the calculations. However, determination of banana yields is usually challenging as quite often it is assumed that 100% of the plants are in production while in reality, it is a fraction of the total plants in a mat/banana stool that are in production at any given year (Hauser and van Asten 2008; Qaim 1999). In calculating streams of costs and benefits for the smallholders, the following assumptions were made:

- Year 0: Establishment phase; no banana yields
- Year 1: Banana yields recorded (25% of total plants are in production)- from farmers' estimates
- Year 2: Banana yields increases (50% of total plants are in production)-from farmers' estimates
- Year 3: Banana yields increases (75% of total plants are in production)-from farmers' estimates
- Year 4: Banana yields increases (100% of total plants are in production)-from farmers' estimate
- Year 5-15: Banana yield declines by 11% every year

The average banana yields reported by farmers at time of study were 11 tonnes ha^{-1}. This was assumed to be the peak yield (year 4) with lower yields calculated before and after year 4. The average weight of one banana bunch was taken as 18 kg (Vlaming *et al.* 2001). On account of nutrient deficiencies, high pest and disease pressure and low management levels, yields of bananas reported in this study were lower than potential yields and or tissue culture banana yields which are in the ranges of 35 to 40 kg per bunch (about 40 tonnes ha^{-1}) (AHBFI 2008). At farm level, banana yield levels of 15 to 20 kg per bunch (15-22 tonnes ha^{-1}) have been reported (The Organic Farmer 2006). This figure may be lower in some sites in Kenya, 4-11 tonnes ha^{-1} (Qaim 1999).

e) Profitability analysis in the year of study

The profitability of banana microcatchments was calculated for the year of study. In a 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 on variable costs. However, annuity of establishment costs was included in profitability analysis in this case to enable comparison with annual crops in Sections 3.4 and 3.5 of the study. The study shows that banana microcatchments were profitable and viable in the year of study with positive gross margins, benefit-cost ratio (BCR-undiscounted) higher than one and gross margins per labour-day higher than opportunity cost of labour of KSh 150-200 per day.

Table 13
Analysis of profitability of banana microcatchments in the year of study

Description	Quantity	Value (KSh/ha)
Banana bunches (Mt/ha)	11	184,259
Banana pseudo-stems (No/ha)	501	9519
Gross income		**193,778**
Variable costs (annual cost of maintenance)		39,900
Establishment cost-annuity		28,946
Total costs		**68,846**
Total labour days	378	
Gross margins (GM)		**124,932**
BCR (undiscounted)		2.8
GM/labour-day		331

Note: 1 US$ = KSh 88 at time of the study.

f) Financial efficiency of microcatchments with bananas

Details of annual income and cost flows are presented in Annex 2. In literature, two scenarios to calculation of financial CBA have been reported (i) determination of net benefits and costs of conservation practice without making comparison with the "without" plot (*in situ* comparison); and (ii) modelling net benefits and costs of conservation as the difference between farm plots "with" and farm plots "without" conservation structure (paired plots), see Annex 1 for details. Both scenarios have been used in calculations in this report enabling readers to compare results with similar work elsewhere in literature. The results of this study show that in the initial years (first two years after establishment), the costs of microcatchments with bananas outweigh the extra income, but in the subsequent years, the income exceed the costs turning the Net Present Value of benefits (NPV) into positive (Table 14). The NPV is however, sensitive to discount rate (interest rate) with higher rates, resulting in lower values of NPV. The net benefit annuity followed a similar trend. The benefit-cost ratios (BCR) of the SWC practice was positive and greater than 1 (within the time horizon of 15 years used in the calculation) and the Internal Rate of Return (IRR) was higher than the market interest rates (10%-14%).

It can thus be concluded that the conservation practices of microcatchments with bananas is financially viable and worth investing in.

Table 14

Financial performance of microcatchments with bananas per hectare

Description	Scenario 1[3]			Scenario 2 (INB)		
Time elapsing before attaining positive net benefit (years)	2			2		
Decision criteria/discount rate	10%	12%	14%	10%	12%	14%
Net Present Value (NPV) (KSh ha^{-1})	806,423	695,684	602,067	429,783	369,754	319,640
Total cost (KSh ha^{-1})	231,682	228,071	225,035	231,682	228,071	225,035
Benefit-cost Ratio (BCR)	3.5	3.1	2.7	1.9	1.6	1.4
Internal Rate of Return (IRR)	53%			65%		
Net Benefits annuity (KSh ha^{-1})	106,023	102,143	98,022	56,505	54,289	52,040
Cost annuity (KSh ha^{-1})	30,460	33,486	36,638	30,460	33,486	36,638

Scenario 1: Net benefits of SWC calculated as the difference between discounted costs and benefits; Scenario 2: The benefits of conservation modelled as the difference in discounted net benefits between farms “with” and “without” SWC practice scenario (Incremental Net Benefits, INB).

3.3.2 **Mulching in tea**

The tea bush (*Camellia sinensis*) in Kenya, is predominantly grown in the highlands (Lower Highlands, LH1) characterised by red volcanic soils and well distributed rainfall ranging between 1200 mm and 1400 mm per annum that alternates with long sunny days. Tea production goes on all year round with two main peak seasons of high crop between March and June, and again and October and December which coincide with the rainy seasons[4]. Tea growing areas in the Upper Tana catchment include the regions of Mt Kenya, the Aberdares, and the Nyambene hills.

a) Establishment costs of tea

Tea is a perennial crop associated with establishment costs at the beginning of the growing cycle, maintenance costs (annual recurrent expenditures) and costs of pruning to form, and to maintain, a convenient plucking table and also to rejuvenate the bushes. In this study, the establishment/investment phase of tea was taken to comprise costs incurred in the first 0-5 years of tea production cycle prior to tea coming into bearing. The results of interviews carried-out in the tea growing areas of Upper Tana, were used to calculate establishment costs of tea (Table 15). The smallholders reported using physical/mechanical methods of land

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[3] For calculations procedures used in Scenario 1 and Scenario 2, see Annex 1.

[4] Tea Board of Kenya: http://www.teaboard.or.ke/industry/growing_production.html

preparation and weed control, thus herbicides such as Gramoxone (paraquat dichloride and Defenuron), for controlling noxious weeds during land preparation were excluded from the calculations. Tea population density in the study areas (theoretically) ranges from 8, 611 plants ha^{-1} (spacing of 1.52 metres x 0.76 metres) to 10,764 plants ha^{-1} (spacing of 1.2 metres x 0.76 metres). An average population of 8600 plants ha^{-1} obtained from this study was used in calculations.

Out of the total cost of establishment in year 0-5, 29% are attributed to field planting while the rest relates to bringing young tea into bearing (Table 15).

Table 15

Average tea establishment costs and costs of bringing young tea into bearing in one hectare of land (year 0-5)

Description	Quantity	Unit	Unit price	Total value Ksh/ha	Labour-days
1. Field planting (Chaining/holing) (Year 0)					
- Labour for clearing	30	Day	150	4,500	30
- Hole digging (manual)	8,600	Number	1.5	12,900	86
- Inorganic fertilizer (Di-Ammonium Phosphate, DAP)	130	Kg	60	7,800	
- Tea seedlings	8,600	Number	6	51,600	
- Labour fertilizing	55	Day	150	8,250	55
- Sub-total (Year 0)				85,050	171
2. Bringing young tea into bearing (formative pruning and tipping-in; year 1-5)					
a) Pruning and tipping					
- 0.15 m"pruning young tea-after year 1	8,600	Number	0.5	4,300	29
- 0.28 m pruning young tea-year 3	8,600	Number	0.5	4,300	29
- 0.41 m pruning mature tea-year 5	8,600	Number	1.5	12,900	86
- Tipping at 0.51m (0.1m above pruning height)-3 rounds tipping	717	Hour	25	17,925	120
b) Mulching/prunings	25,800	Number		25,600	172
c) Fertilizer application (year 1-5)					
- NPK26-5-5 (total year 1-3)	900	Kg	50	45,000	
- NPK26-5-5 (total year 4-5)	12,000	Kg	50	60,000	
- Manure application (applied once)	430	Debe	30	12,900	
- Labour for fertilization	60	Day	150	9,900	
d) Weeding young tea (year 1-5)					
- Weeding total labour over 5 year period	250	Day	150	37,500	250
Sub-total (year 1-5)				230,525	751
- Average per year (year 1-5)				46,105	150
Grand total				315,575	922

1 US$ = KSh 88 at time of study.
Note: Mulching is done every time pruning is done.

The following tools are also used during establishment: fork *jembe*, *panga* and spade. The costs of these tools (two of each type) and other materials were estimated at KSh 5270 (KSh 1054 per year).

b) Maintenance costs of tea

Maintenance costs of tea were quantified by asking the smallholder tea growers. The cost items include pruning, weeding, and fertilization, mulching and plucking (using a plucking stick). After year 5 of tea establishment, pruning in tea was reported to be done after every 3 years (3-year cycle), each time pruning 0.05 m above pruning height until 0.71 m pruning height is reached (20^{th} - 30^{th} year depending on pruning cycle) and then a down pruning is done to 0.53 m pruning height above ground level and the cycle starts all over again. In this study maintenance costs are investigated over a time horizon of 15 years. Pruning is done using a pruning knife (KSh 400-700 per piece) with costs based on number of tea bushes pruned (piece rate) and whether the tea bushes are mature or young. Pruning is done mainly by hired labour. Machine pruning is being introduced in the tea growing areas of Upper Tana; however costs in this study are based on manual pruning practices (using pruning knife), reported by farmers interviewed.

Farmers reported applying farmyard manure to tea, coinciding with the pruning period (June-August period) i.e. manure was applied to pruned tea only. Thus manure application frequency closely follows that of a three-year-pruning cycle. Manure applied is sourced from the farmer's homesteads. The costs involved in weeding tea annually were also investigated. Frequency of weeding tea depends on emergence of weed and weeding is done until the tea canopy smoothers the weeds, after which only light weeding is done.

Interviews with farmers showed that inorganic fertilizers (NPK26-5-5) are applied to tea once every year during the second rains (October-December period). The fertilizers are obtained from Kenya Tea Development Agency (KTDA) on credit. Mulching in tea was reportedly done *in situ* during pruning (prunings left in the field) and does not require additional labour for collection. These farmers' views have been corroborated by other authors who have indicated that farmers leave tea prunings in the field as mulch to maintain soil fertility and protect fields from erosion (Othieno 1981). In a three-to-five year pruning cycle, prunings left in the tea field as mulch have the potential to add about 4 tonnes C ha^{-1}; 350 kg N ha^{-1}; and 40 kg P ha^{-1} and 90 kg K ha^{-1} to the soil (Ranganathan 1973). Tea prunings were valued at the opportunity cost of pressing the prunings down and spreading it around the tea bush which was estimated at KSh. 1 (average) per bush. Previous studies have indicated that smallholder farmers do apply tea prunings (as mulch) at a rate of 10.8 tonnes DM ha^{-1} (Ranganathan 1998). Farmers who do not leave tea prunings in the field collect the prunings and use it as "firewood" or for other purposes (the "without situation").

Tea plucking is done by family labour, although the contribution of hired labour is increasing in the study sites**.** Labour for plucking tea was valued at piece rate i.e. based on the cost of plucking 1 kg of tea (used in paying hired labourers) as given by the farmer and or opportunity cost of plucking 1 kg of tea as given by the farmer.

Maintenance costs include the costs of equipment such as plucking basket, apron, plucking stick, hoes and pruning knife in addition to annual costs of labour (Tables 16 and 17). The annuity costs of materials were added to annual costs of fertilizers to estimate annual costs of materials and equipment incurred by farmers in tea maintenance.

Table 16

Costs of materials and equipment for tea maintenance - one hectare

Description	Quantity	Unit	Unit price (KSh)	Total value (KSh)
Materials (covers the time horizon)				
Plucking basket	3	Number	100	300
Apron	1	Number	750	750
Plucking stick	8	Number	25	200
Hoe	2	Number	835	1670
Pruning knife	2	Number	700	1400
Sub-total				4320
Average cost (annuity)				216
NPK 26:5:5 (annual)	714	Kg	50	35,700
Farm yard manure*	33	*Debe*	30	990
Sub-total				36,690
Total (annual)			_	36,906

1 US$ = KSh 88 at time of study.

Notes:

- It is assumed that a plucking basket (KSh 100 per piece) will be replaced after every 5 years (3 baskets will be required to last 15 years)
- Two pruning knife cost KSh 700 and will last the 15-year period
- Tea yield in the study is 7833 kg ha^{-1}; Assume 6 days plucking week x 52 weeks (312 plucking days yr^{1}); One person plucks 22- 30kg green leaf/day
- A plucking stick is assumed to be replaced after every 2 years
- Apron (plastic) price is in the range of KSh 400-900 depending on quality; an average of 650 is used

-* Manure application done once every 3 years; done three times in year 5-15 of the study (501 *debes* manure: one *debe* contains 20 litres); total applied divided by 15 for annual costing

Results from the study show that tea plucking accounts for about 70% of annual labour demand for maintenance (Table 17). Labour for weeding and fertilization accounted for 11% and 12% of total labour for maintenance respectively. Labour for plucking, pruning and mulching were estimated using “piece” rates. Farmers who do not practice mulching using tea prunings (the “without” situation) incur additional labour for collecting and transporting tea prunings outside the farm for use as “firewood”. This was estimated to be twice the cost of labour for mulching using tea prunings *in situ*.

Table 17

Mean annual labour for tea maintenance for farms with mulching/prunings - one hectare

Description	Quantity	Unit	Unit price (KSh)	Total value (KSh)	Annual cost (KSh)	Labour-days (day)
Weeding	50	Day	150	7500	7500	50
Fertilization	66	Day	150	9900	9900	66
Plucking	7833	Kg	6	46,998	46,998	313
Pruning	8600	Number	1.5	12,900	2580	17
Mulching	8600	Number	1	8600	1720	11
Total					68,698	457

Source: Based on average values from farmers' responses; 1 US$ = KSh 88 at time of study

Notes:

- Plucking and pruning labour is based on piece rates of KSh 6 per kg plucked and KSh 1.5 per tea bush pruned respectively
- Pruning and mulching are done once every 3 years; done four times in year 5-20 of the study; annual estimates obtained by dividing total by 15
- Farms "without" mulching collect and transport prunings for use elsewhere (e.g. for firewood)

c) Benefits of mulching tea

The benefits of mulching tea using tea prunings was taken as the yield (green leaf plucked) increase and resulting gross margin from mulching effects. The tea green leaf plucked by the farmer over one year period was valued at the payment rate (KSh/kg) given to farmers by KTDA (monthly payment rate + total bonus payment). The average payment rate was KSh 46.21 per kg for farmers delivering tea to factories within the three sub-catchments studied.

The average green leaf tea yields reported in this study was below the national average yields, estimated at 2658 kg made tea ha^{-1} (≈ 13,290 kg green leaf ha^{-1}) (KNBS 2008) (Table 18).

Table 18

Tea green leaf yields and value in Upper Tana catchment (standard deviation in parentheses).

Agro-ecological zone	No. of households	Quantity (kg/ha)	Value (KSh/ha)
Tea-Dairy (LH1)	21	7523 (5801)	347,653 (268,052)
Tea-Coffee (UM1)	12	8374 (4080)	386,959 (188,557)
Total	33	7833 (5189)	361,946 (239,787)

d) Profitability of mulching in tea

The profitability of mulching in tea was calculated using similar methodologies as described under microcatchments for bananas. Annuity labour for establishment and bringing young tea into bearing was added to annual labour for tea maintenance in calculations involving gross margins per labour-day. This was to make profitability calculations comparable to those of annual crops included in this study. Results show that mulching in tea is profitable with gross margins being positive, a BCR higher than one, and gross margins per labour-day higher than opportunity costs of labour-day in the study site.

Table 19
Analysis of profitability of mulching in tea in the year of study

Description	Quantity	Value (KSh/ha)
Green tea leaves (kg/ha)	7833	361,946
Gross income		**361,946**
Establishment and bringing young tea into bearing (cost annuity)		46,334
Materials and equipment		36,906
Annual labour for maintenance (days)	458	68,698
Labour-establishment and bringing young tea into bearing (annuity)	135	
Total costs		**68,846**
Total annual labour-days (inclusive of annuity labour-days)	693	
Gross margins (GM)		**293,100**
BCR (undiscounted)		5.3
GM/Labour-day		423

Note: 1 US$ = KSh 88 at time of the study.

e) Financial efficiency of mulching in tea

The results of the study show that about 5 years elapses before positive net benefits are obtained when mulching is practiced in tea by using tea prunings (Table 20). When net benefits of mulching in tea are calculated as the difference between discounted costs and benefits attributed to the performance of the practice over time (scenario 1), the benefit-cost ratios were positive and greater than one at 10% and 12% discount rate, indicating that the practice is viable. However, when the performance of the practice is compared with other farms ("without situation") assuming that such farms exist under similar situation and farmer circumstances, the BCR was lower than 1, but the viability of the practice could still be justified on account that the Internal Rate of Return was higher than the prevailing market interest rates at time of study. The study concludes that it is worth investing in mulching in tea due to a Benefit-cost ratio of 1 or higher and a higher Internal Rate of Return (higher than market rates).

Table 20
Financial performance of mulching in tea per hectare[5]

Description	Scenario 1			Scenario 2 (INB)		
Time elapsing before attaining positive net benefit (years)	5			5		
Decision criteria/discount rate	10%	12%	14%	10%	12%	14%
Net Present Value (NPV) (KSh ha^{-1})	713,211	565,808	446,494	316,462	263,228	220,065
Total cost (KSh ha^{-1})	667,784	594,677	534,095	667,784	594,677	534,095
Benefit-cost Ratio (BCR-discounted)	1.1	1.0	0.8	0.5	0.4	0.4
Internal Rate of Return (IRR)	31%			89%		
Net Benefits annuity (KSh ha^{-1})	93,768	83,074	72,693	41,606	38,648	35,829
Cost annuity (KSh ha^{-1})	87,796	87,313	86,955	87,796	87,313	86,955

Scenario 1: Net benefits of SWC calculated as the difference between discounted costs and benefits; Scenario 2: The benefits of conservation modelled as the difference in discounted net benefits between farms “with” and “without” SWC practice scenario (Incremental Net Benefits, INB).

3.3.3 **Zero tillage in coffee**

a) Description of practice

Coffee is grown on smallholder and large-scale farms in Kenya (mainly Arabica). Traditional varieties found at farm level include SL28, SL34 and K7 (spacing of 2.74 x 2.74 metres; though new varieties such as Ruiru II (spacing of 1.83 x 1.83 metres) are increasingly being planted. The study focused on smallholder farming systems irrespective of variety grown. In the study zero tillage was taken as the application of herbicides in coffee fields to manage weeds in contrast to conventional manual tillage practices (using hand hoes) for land preparation and weeding. Herbicide use in conservation and no-till systems kill the foliage of weeds, though the roots remain to decompose into organic matter and thus help prevent soil erosion. Ten smallholders were interviewed about coffee establishment costs, maintenance costs; application of herbicides and other farm inputs and about coffee outputs (coffee cherries and clean coffee) and associated prices. The area conserved through zero tillage was small, average of 0.57 hectares.

b) Establishment costs of coffee

Coffee is a perennial crop and thus has establishment costs and annual maintenance costs. However, the application of herbicides to control weeds was investigated as an “annual cost”. About 50% of establishment costs is attributed to labour for digging planting holes while a further 20% is attributed to planting materials (coffee seedlings), Table 21.

[5] For calculations procedures and rationale used in Scenario 1 and Scenario 2, see Annex 1.

Table 21

Establishment cost of coffee - 1 hectare of land (excluding tools)

	Rate	Quantity	Unit	Unit price (KSh)	Total value (KSh)
Digging holes-labour	spacing of 2.74 x 2.74 m^2	1330	holes	40	53,200
Manure	1 *debe* (20 litres)per hole	1330	holes	10	13,300
NPK (TSP)	0.1 kg per hole	133	kg	50	6650
Furadan (6 months later)	10 g/hole	13,300	grams	0.6	7980
CAN (Applied 6 months later)	50 g/tree	66.5	kg	45	2993
Planting material		1330	number	20	26,600
Labour fertilization + planting		65	Days	150	9750
Herbicides					5721
Total costs					126,194

Notes: In one day, 5 holes of 0.6 m x 0.6 m x 0.6 m deep can be dug; Mulching not observed at time of establishment; Labour for digging holes-266 days; labour for fertilization and planting - 65 days (total 231 labour-days with annuity of 34 days per year).
Source: Authors interview survey, 2011.

Complementary tools required by the farmer to practice the technology were also inventoried and their costs worked out as in Table 22.

Table 22

Establishment cost of coffee under zero-tillage - 1 hectare (tools required)

Tools for establishment	Quantity	Unit	Unit price	Total value KSh/ha
Panga	2	Number	200	400
Fork *jembe*	2	Number	835	1670
Knapsack sprayer	2	Number	3400	6800
Total				8870
Annuity cost of tools				1302

b) Annual maintenance costs of "zero-tillage in coffee"

Annual maintenance costs of coffee are presented in Table 23. Coffee management is labour intensive, with labour accounting for about 77% of total annual labour for maintenance (Table 23). The main difference between farmers "with" and "without" practices was the use of herbicides for controlling weeds. Farmers not using herbicides to control weeds spent about 167 days ha^{-1} $year^{-1}$ on manual land preparation and weed control (valued at an average of KSh 33,354 ha^{-1} $year^{-1}$). All factors constant, replacing herbicide use with manual tillage will see annual maintenance costs rise by 31%. Other authors have indicated that the use of conservation tillage (using Glyphosate and Lasso-Atrazine) compared to conventional tillage (digging and hand-weeding) saves up to 50% of the cost of production (Muthamia *et al.* 2001).

Table 23
Annual maintenance costs of practice of zero-tillage in coffee

Description	Quantity	Unit	Unit price	Total
Labour				
Land tilling*	44	Day	200	8800
Inorganic fertilizer application	40	Day	200	8000
Organic fertilizer application	33	Day	200	6600
Pesticide application	21	Day	200	4200
Herbicide application	10	Day	200	2000
Pruning	78	Day	200	15,600
Harvesting	80	Day	200	16,000
Transport handling	13			2500
Sub-total	319	Day	200	63,700
Inputs and materials				
NPK fertilizers	33	Kg	50	1650
CAN	33	Kg	40	1320
Manure - FYM	7980	Kg	1	7980
Herbicides	16.7	Units	355	5921
Pesticides	1.92	Units	936	1798
Sub-total				18,669
Total				82,369

*Reduced land tilling due to use of herbicides.

c) Coffee yields and gross margins under zero tillage

Coffee yields reported by the farmers in this study under zero tillage were low, 4.7 tonnes cherry ha^{-1}. Other authors have reported smallholder coffee yields about 400-600 kg ha^{-1} clean coffee (or 2.8-4.2 tonnes cherry per hectare) (Global Development Solutions 2002). Since 1999, yield rates for smallholder farmers in Kenya have declined dramatically where it is estimated that farmers are only harvesting 3-10 kg of cherry/plant (4-13 tonnes cherry ha^{-1}), where in the past at least 30 kg cherry/plant was possible while maximum yield that can be attained can be up to 45 kg cherry/tree. Some new coffee varieties (e.g. Batian released in 2010 in Kenya) can yield as much as 3.56-5 tonnes clean coffee (about 25-35 tonnes cherry ha^{-1}) (Kimemia 2010). Studies have shown that grain yields go up by 30% when conservation tillage (using Glyphosate) is used (Muthamia *et al.* 2001) compared to conventional hand digging and weeding; while the use of Lasso Atrazine after tilling makes yield increase by up to 23% over hand weeding. However, there are limited studies on the effects of herbicides on coffee yields in Kenya (Kamau 1980). In this study, it is assumed that the yields of coffee grown without zero tillage and under erosion situation is lower by 25% initially, and thereafter declines each year by a margin of 2% due to soil erosion. The yields of coffee under zero-tillage are assumed to be stable.

The smallholder coffee sector is currently being revived from decades of deterioration and poor agronomic management attributed to low prices. The average price farmers obtained for their cherries in this study was KSh 59 per kg while the performance of coffee under zero tillage is given in Table 24. The gross margins were positive in the year of study and the undiscounted benefit-cost ratio was also higher than 1, indicating that the practice was viable. Annual labour for maintenance of the practice was added to annuity labour for establishment in calculating gross margins per labour- day. This was to make it comparable with that of annual crops.

Table 24
Coffee performance under zero tillage.

Description	Quantity	Unit	Unit price (KSh)	Total
Coffee production	3587	Kg	59	212,407
Annuity- establishment costs				18,528
Annuity-other materials and tools				1302
Labour	319	Day	200	63,700
Inputs (fertilisers + crop protection)				18,669
Total costs (annual)				102,199
Establishment labour-annuity	34	Day		
Gross margins (GM)				110,208
BCR (undiscounted)				2.1
GM/Labour-day				312

d) Financial efficiency and productivity of zero-tillage in coffee

It takes about 3 to 4 years for a coffee plant to mature and will then produce coffee beans for about 15 years of prime production, though the plant can live and continue producing for 60 years[6]. In this study, the coffee plant is taken to start producing three years after establishment. It reaches its peak production in the sixth year, although the yields are assumed stable under zero-tillage in this analysis. The financial efficiency of zero tillage in coffee was assessed for 15 years and details are in Annex 4 and summary is in Table 25. When the net benefits of zero-tillage is modelled as the difference between “with” and “without” situation (scenario 2), then returns (net present value) turn positive within a shorter time period (3 years after establishment) than otherwise (scenario 1). The benefit-cost ratio realised was 1 within the time horizon of 15 years that the analysis was done (discount rates of 10% and 12%). The Internal Rate of Return was higher than the prevailing market interest rate (cost of capital) of 12%. It is envisaged that when farmers use zero-tillage practices in coffee, improve other agronomic practices and market prices for coffee improves, then the benefit-cost ratio might be expected to rise above 1. The BCR was not greater than one, partly due to low coffee prices at time of study. However, the viability of zero-tillage is justifiable on account that the internal rate of return was higher than the prevailing market interest rates; and that farmers are already implementing the practice.

[6] coffee facts: www.cofeefair.com

Table 25
Financial efficiency of zero-tillage coffee per hectare[7]

Description	Scenario 1			Scenario 2 (INB)		
Time elapsing before attaining positive net benefit (years)	6			3		
Decision criteria/discount rate	10%	12%	14%	10%	12%	14%
Net Present Value (NPV) (KSh ha^{-1})	481,244	388,016	310,712	574,228	500,271	438,856
Total cost (KSh ha^{-1})	765,368	699,391	643,911	765,368	699,391	643,911
Benefit-cost Ratio (BCR-discounted)	1.0	1.0	0.5	1.0	1.0	1.0
Internal Rate of Return (IRR)	30%					
Net Benefits annuity (KSh ha^{-1})	63,271	56,970	50,587	75,496	73,452	71,450
Cost annuity (KSh ha^{-1})	100,626	102,688	104,835	100,626	102,688	104,835

Scenario 1: Net benefits of SWC calculated as the difference between discounted costs and benefits of the practice; Scenario 2: The benefits of conservation modelled as the difference in discounted net benefits between farms “with” and “without” SWC practice (Incremental Net Benefits, INB).

3.3.4 **Riverine protection**

a) Description of practice

A total of 24 smallholders who have conserved riverbanks were interviewed. The interview sought to obtain riverbank protection establishment costs, maintenance costs and product value of materials harvested from riverbanks. By law, farmers are required to conserve riverbanks (Box 1). The farmers interviewed had conserved an average of 0.29 hectares of riverbank in which they had planted grasses and trees either sole or in combination. The average width of the conserved area was 21 metres. The grasses planted include fodder grasses (napier grass, Kikuyu grass) and local grasses while different species of trees were planted mainly indigenous species. The main grass planted in the riverbank is napier grass. Napier grass (*Pennisetum purpureum*) has become by far the most important fodder grass due to its wide ecological range (from sea level to over 2,000 m.a.s.l.), high yield and ease of propagation and management; sometimes herbaceous legumes or fodder shrubs are associated with places where napier grass has been planted. Studies on the impacts of soil erosion and yield loss in riverbanks are limited. In this study it is assumed that conservation of riverbanks (slopes of 20-40%) using trees, grasses and shrubs has similar impacts as that of trees and grass hedgerows. In a study in central Kenya, the yields of calliandra-napier hedgerow increased by 33% in “before and after” experiment conducted to determine the effects of hedgerow in controlling erosion (Angima *et al.* 2002). Tree hedges and grass either sole or in combination have also been shown to reduce soil loss by margins of 3-49% compared to non-hedged plots (Angima *et al.* 2000).

[7] For calculations procedures used and rationale for Scenario 1 and Scenario 2, see Section 2.2.6

Box 1
Riverine protection

- Under the Environmental Management and Coordination (Water Quality) Regulations of 2006, the regulations state "No person shall cultivate or undertake any development activity within full width of a river or a stream to a minimum of six meters and a maximum of thirty meters on either side based on the highest recorded flood level".
- The Agriculture (Basic Land Usage) Rules also provides for the protection of river banks and states "Any person who, except with the written permission of an authorized officer, cultivates or destroys the soil, or cuts down any vegetation or de-pastures any livestock, on any land lying within 2 metres of a watercourse, or, in the case of a watercourse more than 2 meters wide, within a distance equal to the width of that watercourse to a maximum of 30 meters, shall be guilty of an offence".
- The Physical Planning (Sub Division) Regulation of 1998 in section 15 Part (c) states that "Wayleaves or reserves along any river, stream or water course shall be provided of not less than 10 meters in width on each bank, except in areas where there is an established flooding".

While appreciating farmers concerns about leaving up to 30 meters of their land as riparian reserves, especially with the reduced parcels of land in the Upper and Middle zones, it is quite clear from several legislations that the practice today where they are cultivating on the river banks is against the law. The adverse impacts of cultivating riverbanks will also hurt the same local communities in terms of river water quality and discharge. In this regard, the following is proposed (i) At least a minimum width that should not be cultivated is left intact (6 metres as in EMCA's water quality regulations) (ii) While the rest of the land (6- 30 metres) should be put under land use practices that are compatible with riverbank protection.

Source: Extract from Final Report on Impact Assessment Study for Mount Kenya East Pilot Project, 2009

b) Establishment costs of riverbank protection

The study obtained information from farmers on materials and labour they currently use in establishing and protecting riverbanks (Table 26). A figure of KSh 38,333 ha^{-1} was calculated as establishment costs (excluding tools) based on farmers estimates with 11% of total costs attributed to lay-out activities. Costs incurred on tools and equipment required for establishing and maintaining riverine areas are presented in Table 27. The tools and equipment are assumed to last the full length of time horizon of the analysis of 15 years with cost annuity of KSh 847.

Table 26
Costs incurred by farmers in establishing and yearly maintenance of riverbanks - 1 ha

Description	Quantity	Unit	Unit price (KSh)	Total value (KSh)
Establishment costs				
(i) Lay-out				
– Pegs	40	Number	20	800
– String	7	Number	200	1333
– Labour: lay-out	13	Day	150	2000
Sub-total				4133
(ii) Other inputs				
– Seedlings	500	Number	20	10,000
– Labour: digging holes	20	Day	150	3000
– Labour: planting	13	Day	150	2000
DAP (Inorganic fertilizer)	0			0
Manure	0			0
Watering	20	Month	960	19,200*
Sub-total				34,200
Total (establishment)				***38,333***
Establishment cost annuity				***5628***
Annual maintenance				
Labour: slashing/weeding	7	Number	640	4267
Labour: pruning/other	7	Number	640	4267
Total (maintenance)				**8533**

*Equivalent to 128 labour-days; total labour-days for establishment: 174;
Annual maintenance labour-days: 57 labour-days.

Table 27
Tools and equipment farmers use in riverine protection - 1 ha

Materials	Quantity	Unit	Unit price (KSh)	Total value (KSh)
Watering can	2	Number	400	800
Fork *jembe*	2	Number	835	1670
– *Panga*/Slasher	2	Number	550	1100
– File	2	Number	200	400
– Hammer	2	Number	400	800
– Tape measure	1	Number	1000	1000
Total				5770
Cost annuity				847

The benefits that farmers get in implementing riverine protection are presented in Table 28 for the year of study (2011). The fodder grasses harvested were mainly napier. Dry matter (DM) yields of napier have been reported to be in the range of 4 and 20 tonnes DM per hectare although on-station research yields can be as high as 40 tonnes DM per hectare (Wouters 1987). Other on-farm research in central Kenya has indicated figures of 9-27 tonnes DM per hectare (Onduru *et al.* 2006). Farmers use of trees harvested from riverine areas were in the form of poles (building poles), firewood and to a small extent timber. Trees for timber fetch better prices and with improved sustainable management and harvest of trees planted in the riverine areas, the farmers income can be higher than that reported in this study.

Table 28

Analysis of benefits and costs on an annual basis for riverine protection – one hectare

Annual benefits	Description	Value (KSh/ha)
Grasses (fodder and local)	111,915 FM kg*	266,875
Poles	Lump sum	11,340
Poles/timber	Lump sum	34,719
Fuel wood	Lump sum	20,622
Total benefits		**333,556**
Establishment cost annuity		5628
Annuity cost-tools and equipment		847
Annual maintenance cost		8533
Labour-days (layout and establishment)	174	
Labour-days (annual maintenance)	57	
Total cost (annual)		15,008
Gross margins		318,548
Benefit-cost Ratio (undiscounted BCR)		22.2**
Gross margins/labour-day		1379

*About 15.7 tonnes DM ha^{-1}; Costs and benefits based on farmers responses; ** The high BCR indicates that the practice is profitable and worth investing in.

e) Financial efficiency and productivity of riverine protection

The streams costs and benefits discounted over a period of 15 years are shown in Annex 5. The year of establishment is regarded as base year (year 0). While grasses can be harvested one year after establishment, trees are assumed to take longer (5 years) to reach productive stage either for firewood or for other tree products. The costs of tools and equipment are assumed spread equally over the 15-year period. Riverine protection where fast growing fodder grasses are planted together with trees attains a positive net present value, one year after the year of establishment (2 calendar years). This was probably due to fast growing grasses like napier planted within the riverine areas. The observations are consistent with de Graaf (1996) who reported that tree crops take between 2-5 years before they become effective. The benefit-cost ratio was higher than one and the Internal Rate of Return was higher than the cost of capital (market interest rates) indicating that the practice is profitable and worth investing in.

Table 29
Financial efficiency of riverine protection (15 year time horizon)

Description	Scenario 1		
Time elapsing after the base year before attaining positive net benefit (years)	1		
Decision criteria/discount rate	10%	12%	14%
Net Present Value (NPV) (KSh ha^{-1})	2,169,198	1,923,444	1,717,809
Total cost (KSh ha^{-1})	115,082	107,990	102,027
Benefit-cost ratio (BCR-discounted)	18.8	17.8	16.8
Internal Rate of Return (IRR)			546%
Net Benefits annuity (KSh ha^{-1})	285,193	282,408	279,675
Cost annuity (KSh ha^{-1})	15,130	15,856	16,611

Scenario 1: Net benefits of SWC calculated as the difference between discounted costs and benefits of the practice;

3.4 Structural SWC measures with annual crops

3.4.1 Description of practices studied

Structural measures studied include bench terraces, *fanya juu* terraces, cut-off drains, retention/infiltration ditches and stone lines. These measures are formed from earth, stone or masonry and are designed to protect crop land from uncontrolled run-off and erosion and to retain water where it is needed. 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 runoff and increasing infiltration of water into the soil (Thomas *et al.* 1997). In the research site, they are formed through excavation, although the same can also develop from grass strips or *fanya juu* terraces. 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 overtopping by runoff and a berm/ledge to prevent the embankment soil from sliding back into the trench. Cut-off drains (or diversion ditches) are graded channels with a supporting ridge or bank on the lower side constructed a cross a slope to intercept surface runoff and convey it safely to an outlet such as a waterway. Retention ditches are designed to catch and retain all incoming runoff and hold it until it infiltrates into the ground. They are constructed at zero gradient (level) with closed ends and wide and deep enough to hold expected runoff. Contour stone line consists of a single line of stones on the contour and is different from a stone bund. The latter's height and base width is more (25 cm high; 35-40 cm wide) with the base set in a shallow trench, 5-10 cm deep to reduce the risk of being swept away by water. Except for stone lines, structural measures considered in this section were stabilised by grasses on terrace embankments or risers (Thomas *et al.* 1997; WOCAT 2007).

3.4.2 Investments in structural measures

Investment costs considered in this study comprised two costs centres (i) costs that farmers incur 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. The lay-out costs were investigated for all the sub-catchments studied and averages are presented in Table 30. Most of the farmers in the study catchments reported using stones or plank of wood to drive pegs down when "pegging the contour" while a few others use hammers. The cost of the hammers was thus excluded in the equipment lay-out costs. Materials for laying out terraces include spirit and line level, levelling board and string, pegs, and *pangas*.

Costs incurred by farmers in establishing grass stabilisers include labour and materials. An average figure of 28 labour-days per hectare (KSh 4165 per hectare) was estimated by farmers for establishing grass on the embankments/risers of SWC structures (Table 31). The grass is established on soil thrown either uphill of the channel (as in *fanya juu*) or downhill of the trench (as in cut-off drains); thus land preparation does not have to be done a fresh. Apart from labour, the study estimated the costs of materials required to establish the grass stabiliser to be KSh 72,990 per hectare. The materials comprise planting materials (e.g. napier cuttings, napier splits and other grasses) and farmyard manure.

Table 30
Lay-out costs for structural measures along the contour - one hectare

Description	Quantity	Unit	(KSh/ha)
Labour	25	Days	5000
Spirit and line level	1	Number	250
Leveling board + string	1	Number	350
Pegs	1	Lump sum	5000
String	1	Number	200
Panga	1	Number	300
			11,100

Table 31
Costs of establishing grasses on the embankments of SWC structures

Description	Quantity	Value
Labour-establishment (days)	28	4165
Planting materials (sack)	83	24,990
Manure (pick-up)	40	48,000
Sub-total		77,155

Source: Authors interview survey, 2011.

Investment costs in stone line include labour and stones required. In the study site farmers, obtain stones locally at no cost either within their farms or in the neighbourhood especially in the Lower Midland zones covered by this study. However, stones were valued at opportunity costs of using them as building gravel. Average estimates from this study were that three 7-tonne lorry-loads of stones were required to build stone lines on one hectare of land (483 metres running length) costing an average of KSh 31,050 per lorry load. The average labour demand from households interviewed stood at 67 labour-days per hectare worth KSh 13,400 per hectare. The highest investment costs were associated with bench terraces and cut-off drains. This is partly because of the high labour demand required for excavation and construction of the structures. Also because of the large quantity of water that cut-off drains are intended to cater for, they are usually trapezoidal in section and have larger capacities than channel terraces.

Table 32
Investments costs in structural SWC measures.

Description	Bench terrace		*Fanya juu*		Cut-off drain		Infiltration ditch		Stone lines	
		Value		Value		Value		Value		Value
No. of respondents	46		91		25		42		7	
Lay-out costs		11,100		11,100		11,100		11,100		11,100
Materials/tools (KSh)		3035		3035		3035		3035		3035
Labour-establishment (days)	263	52,529	186	37,158	210	42,000	208	41,600	67	13,400
Sub-total		66,664		51,293		56,135		55,735		27,535
Grass stabiliser-establishment		77,155		77,155		77,155		77,155		0
Stones										31,050
Total		143,819		128,448		133,290		132,890		58,585

Labour-days for establishing grass stabiliser 28 days (KSh 4165); labour for structure lay out: 25 days costing KSh 5000.

The labour requirements for establishing bench terraces and *fanya juu* were within the range obtained in west Usambara highlands of Tanzania of 66-354 and 43-222 labour-days per hectare respectively on stable soils with slopes of 5-55% (Tenge *et al.* 2005). In central Kenya labour-days for construction of *fanya juu* terraces have been reported to be in the range of 136-281 labour-days per hectare for land with 5-35% slope (Wenner 1980). In eastern Kenya and in El Salvador, labour-days for construction of *fanya juu* terraces have been reported to be in the range of 84-150 labour-days ha^{-1} (Wall 1981 Barret 1985). Other studies in eastern Kenya have reported 253-310 labour-days ha^{-1} for construction of bench terraces (Wall, 1981). The labour demand for establishing bench terraces can go up to 500 labour-days ha^{-1} as reported in the Philippines (Cruz *et al.* 1988). Studies in Peru have indicated the labour demand for establishing infiltration ditch to be 205 labour-days ha^{-1} (Alfaro-Moreno 1987).

The labour demand for stone lines in this study was within the range of 51-166 days ha^{-1} reported in Burkina Faso where the stones were brought from 2 to 4 km away using lorry or donkey carts to build 200 to 400 m ha^{-1} of stone rows (de Graaf 1996). Labour for constructing stone terraces in eastern Kenya have been reported to be 36 and 62 days ha^{-1} for small and large stone bunds respectively (Ellis-Jones and Tengberg 2000). Other authors have reported 219 labour-days ha^{-1} 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.

Equipment and materials are investment items that farmers require for implementing SWC measures. The tools farmers need for constructing structural measures of SWC structures were similar across the structural SWC practices studied here. These tools include the fork *jembe*, spade, *panga* and mattock (pick-axe). Estimates from this study show that a total of KSh 3035 would be required by farmers to purchase tools sufficient for complementing conservation activities and maintenance of SWC structures on one hectare of land. In most parts of the catchment hired labourers usually come with their own tools to do conservation work at no extra pay on top of the agreed upon wage. The costs of tools are lower than the labour costs for establishing the structural measures studied. This finding corroborates that of Tenge *et al.* (2005) where the major cost of implementing SWC structures was reported to be labour rather than equipment and tools often provided in some projects as incentive for supporting farmer’s conservation efforts. Labour cost for establishing the structures with grass stabiliser accounted for 43%, 38% and 38% of total investment costs for bench terraces;

and cut-off drains and infiltration ditches respectively. These figures were 36% and 31% for *fanya juu* and stone lines respectively.

3.4.3 **Annual maintenance costs of structural measures**

a) Structural measures

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. The costs of maintaining stabiliser grasses on structure risers and/or embankments were studied across the five structural measures and agro-ecological zones with average costs presented in Table 33. Annual maintenance of structures required 82 labour-days ha^{-1} (worth KSh 12,300) in addition to manure applied at 10 tonnes ha^{-1} (worth KSh 12,000). The stone lines in this study did not have grass stabilisers and thus farmers did not incur costs on the same.

Table 33
Annual costs of maintaining stabiliser grasses on SWC structure risers and embankments - one hectare

	Quantity		Value (KSh)
	Pick-ups	Labour-days	
Manure	10		12,000
Labour: weeding		25	3750
Labour: fertilisation		40	6000
Labour: harvesting		10	1500
Labour: transporting		7	1050
Total	10	82	24,300

The labour for annual maintenance of the SWC structures differs from practice to another with infiltration ditch having the highest labour demand and cut-off drain having the second lowest labour demand for annual maintenance (Table 34). It is not clear from this study why this should be so. However, observations at field level indicated that farmers frequently scoop soil out of the infiltration ditch and that the cut-offs are not as regularly maintained as infiltration ditches. The structure with the lowest labour demand for annual maintenance was the stone lines. This is partly due to the fact that once the stone lines are constructed little labour is then required for its maintenance.

Table 34
Annual maintenance labour for SWC structures - one hectare

	Labour (days/ha)	Value (KSh/ha)
Bench terrace	58	8700
Fanya juu	41	6150
Cut-off drain	39	5850
Infiltration ditch	72	10,725
Stone lines	10	1500

Annual maintenance labour for bench terraces was comparable to 55 days ha^{-1} reported in Vietnam (Stocking and Abel 1992). However, Sheng (1986) reported a lower figure of 42 labour-day ha^{-1} in Jamaica as an annual labour for maintaining bench terraces. The annual maintenance labour required for stone lines was comparable to that reported in literature of 12 days ha^{-1} in Mbeere District, eastern Kenya (Ellis-Jones and Tengberg 2000). However, annual labour maintenance figures obtained for this study were higher than that reported by de Graaf (1996) in Burkina Faso of 3-6 labour-days ha^{-1}. Similarly, the figures reported for annual maintenance of *fanya juu* in this study were higher than that reported in eastern Kenya of 18 days ha^{-1}. The differences could be attributed, partly, to diverse scenarios and techniques used in maintaining the stone lines (WOCAT 2007).

b) Annual costs of maize intercrop (with beans) grown on terraced land

Variable costs incurred in growing crops on the terraced land were investigated in this study for the structural SWC measures. These costs include labour and materials for production such as seeds, organic and inorganic fertilisers and crop protection materials (pesticides). The average quantities and costs for one hectare of land for these inputs are presented in Table 35.

Table 35
Variable costs for maize intercrop (beans) production on land with structural measures – one hectare

	Bench terrace		*Fanya juu*		Cut-off drain		Infiltration ditch		Stone lines	
	Qty	Value	Qty	Value	Qty	Value	Qty	Value	Qty	Value
Labour										
– Labour land preparation (days)	43	6910	54	9004	31	5754	50	8204	39	7243
– Labour others (days)	279	131,371	152	22,788	134	23,303	323	22,493	136	20,015
Sub-total	*322*	*138,281*	*206*	*31,792*	*165*	*29,057*	*373*	*30,697*	*175*	*27,258*
Materials										
– Maize seeds (kg)	25	4326	26	5240	24	5944	19	5495	23	7581
– Beans seeds (kg)	24	2766	69	10,796	20	2387	88	3857	112	13,889
Manure (wheelbarrows)	60	9639	55	3833	69	3510	73	37,091	90	4507
Basal fertilizers (kg)	102	83,719	111	79,959	69	57,778	136	55,130	171	22,865
Topdressing fertilizers (kg)	71	11,616	67	30,735	29	30,872	245	4010	23	1150
Pesticides (lump sum)		773	29	1649		685		1517		1,230
Sub-total		*112,839*		*132,212*		*101,176*		*107,100*		*1,222*
Total		251,120		164,004		130,233		137,797		78,480

Qty = Quantity; Values are in KSh ha^{-1}.

The actual quantities and costs incurred on inputs vary from farmer to farmer and does not imply that growing maize intercropped (with beans) on a given piece of land terraced by a given conservation structure incurs greater costs than the other. The variation is due to local farmer practices rather than being an attribute of the conservation structure. Such kind of variability in volumes of variable costs have also been observed in similar studies elsewhere (Ellis-Jones and Tengberg 2000; Demtew 2006).

3.4.4 **Benefits of SWC structures**

The benefits of structural SWC measures were identified to be an increase in crop yields and grasses planted on the terrace risers and or embankments. Crop yields comprised maize and bean grains planted in the terraces as well as residues/stover obtained after grain harvest. The annual yields of grains and stover and grasses were obtained from the farmers interviewed in addition to costs incurred in production. The costs and benefits of SWC structures were used in calculating the gross margins of conservation practices in the year of the study (Table 36).

The yields of maize grains observed in this study were lower than expected yields (2.5 to 7 tonnes ha^{-1}) for common maize varieties (composites and hybrids) planted in the study area (MoARD 2002) except for comparable yields attained with stone lines. The differences in yields are a reflection of differences in the 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^{-1} 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 (semi-humid to semi-arid) of this study appeared to have reported exceptionally higher grain yields. Previous studies in the semi-humid to semi-arid areas have indicated that maize grain yields rarely reach 2 tonnes ha^{-1} in these areas (Onduru and Du Preez 2008).

Table 36
Grain yields and gross margins per hectare achieved with SWC structural measures

	Bench terrace		*Fanya juu*		Cut-off drain		Infiltration ditch		Stone lines	
Description	Qty	Value	Qty	Value	Qty	Value	Qty	Value	Qty	Value
Maize grain yields (kg/ha)	1636	56,097	1547	39,216	1671	61,877	1513	41,815	2542	91,235
Beans grain yields (kg/ha)	196	19,844	369	20,482	396	12,590	163	9359	476	57,143
Sub-total		*75,941*		*59,698*		*74,467*		*51,174*		*148,378*
Crop residues (KSh)		30,346		25,165		18,591		22,102		66,729
Napier grass (FM kg/ha)	145,461	461,189	102841	369,167	188937	328,072	229,254	357,360	0	0
Gross income		567,476		454,030		421,130		430,636		215,107
Maize/beans-production costs		251,121		164,004		130,232		137,798		78,480
Napier grass-production costs		101,455		101,455		101,455		101,455		0
Establishment cost of structure-annuity		9788		7531		8243		8189		8602
Annual maintenance cost of structure		8700		6150		5850		10,950		1500
Total costs		371,064		279,140		245,780		258,392		88,582
Total labour-days	753		543		524		764		252	
Gross margins (GM)		196,412		174,890		175,350		172,244		126,525
BCR (undiscounted)		1.5		1.6		1.7		1.7		2.4
GM/Labour-day		261		322		335		225		502

Qty = Quantity; Values are in KSh ha^{-1}; BCR = Benefit-cost Ratio.

Assuming a dry matter fraction of 0.14 for napier, the yields obtained in this study were higher for infiltration ditches (32.1 tonnes DM ha^{-1}) and cut-off drains (26.5 tonnes DM ha^{-1}) than for bench terraces (20.4 tonnes DM ha^{-1}) and *fanya juu* terraces (14.4 tonnes DM ha^{-1}).

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.

3.4.5 Financial cost-benefit analysis of the structural measures

In this study, the year of establishing the SWC structure was considered base year (year 0) and successive years (15-year period) were considered in calculating Net Present Value (NPV). The results of the study show that the SWC structures studied will begin to pay 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 has been recovered. 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 central Kenya 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 37
Financial efficiency of studied SWC structural measures (15-year time horizon; values for NPV and INB x 1000)

	Discount rate	Bench terrace	*Fanya juu*	Cut-off drain	Infiltration ditch	Stone lines
Time elapse after base year*		1	1	1	1	<1
NPV	10%	2009.9	1844.4	1848.4	1826.5	783.6
	12%	1784.7	1638.1	1641.2	1621.7	695.6
	14%	1595.4	1464.7	1467.0	1449.4	621.5
BCR (discounted)	10%	1	1.1	1.4	1.3	1
	12%	1	1.1	1.3	1.2	1
	14%	1	1.1	1.3	1.2	1
IRR (%)		197	202	195	194	189
INB	10%	3556.9	2802.3	2521.3	2624.8	643.5
	12%	3168.0	2494.3	2242.1	2335.2	566.2
	14%	2841.0	2235.5	2007.5	2091.7	501.5

*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 and IRR = Internal Rate of Return

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 37). 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 did 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 values of NPV. The practices studied are viable and financially attractive (BCR of 1 and higher). The Internal Rate of Return (IRR) was also higher than the cost of capital (market interest rate). The Incremental Net Benefit (INB), the difference between net benefit of "with" practice and "without" practice also shows that the practices were profitable over the time horizon considered for this study. The study therefore concludes that the practices of bench terraces, *fanya juu*, cut-off drains, and infiltration ditches and stones lines are profitable in the Upper Tana catchment.

3.5 Investment in agronomic and vegetative SWC measures with annual crops

3.5.1 Description of practices studied

Agronomic and vegetative measures studied include trash lines, grass strips, contour tillage and planting, and contour ridging. Trash lines are constructed by laying plant residues or trash in lines along the contour. Trash lines slow down the flow of runoff and trap eroded soil (Thomas *et al.* 1997). The trash lines in the study areas did not have pegs on the lower side to prevent the trash being washed away. A grass strip is a narrow band of grass planted on cropland along the contour. The grass strips studied were mainly of napier grass fodder, although different grasses can be grown on the band. 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 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.

3.5.2 **Investments in agronomic and vegetative measures**

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. These costs include lay-out costs for the two structures but also the costs of establishing napier grass strips. The establishment costs have been presented in Table 38. The costs of lay-out of the SWC measures were similar to what was recorded for structural measures since the same materials are used according to the farmers view. However, the cost of tools reduced as farmers reported using fewer tools (farmers using fork *jembes* and *pangas*).

Table 38
Investments costs in agronomic and vegetative SWC measures

	Trash lines		Grass strips	
Description	Quantity	Value	Quantity	Value
No. of respondents	16		61	
Lay-out costs		11,100		11,100
Materials/tools (KSh)		1435		1435
Sub-total		12,535		12,535
-Labour-annual maintenance days)	22	4400	58	
Grass strip				
-Land preparation-labour		0	30	4500
-Planting materials (sack)		0	83	24,990
-Manure (pick-up)		0	40	48,000
-Labour (planting; manure application)		0	28	4165
Sub-total		16,935		81,655
Total		**16,935**		**94,190**

The labour requirements for establishing napier grass strips were within range of 7-59 day ha^{-1} obtained by Tenge *et al.* 2005. Working in eastern Kenya, Ellis-Jones and Tengberg (2000) reported labour for establishing trash lines of 10-20 days ha^{-1}, which was comparable to figures obtained in this study. Labour costs for establishing trash lines are annual costs.

3.5.3 **Annual maintenance costs of SWC measures**

a) Annual maintenance costs

Contour tillage and planting, and ridging are made every planting time (annual costs). However, napier grass strips have annual maintenance costs. The average maintenance costs of napier grass strip was estimated as KSh 24,300 ha^{-1} yr^{-1} based on farmers responses (see Table 39). The average annual labour demand for annual maintenance of grass strips was estimated at 82 labour-days ha^{-1} (this study).

Table 39
Annual maintenance costs of napier grass strip

	Quantity	Value (KSh ha^{-1})
Manure (pick-up truck load)	10	12,000
Labour - weeding (days)	25	3750
Labour - fertilisation (days)	40	6000
Labour - harvesting (days)	10	1500
Labour - transporting (days)	7	1050
Total		24,300

b) Annual costs of maize intercrop (with beans) grown on terraced land

The variable costs of maize intercrop (with beans) grown in conserved land using agronomic and vegetative measures are presented in Table 40. The average costs of maize production vary from farmer to farmer. Farmers in the semi-humid to- semi-arid zones (Lower Midlands) incurred high production costs for maize/beans, a situation partly attributed to high labour inputs. A part from labour for land preparation, other labour attributes captured in this study included labour for planting, weeding, pesticides, harvesting, transporting and handling, and threshing.

Table 40
Variable costs for maize intercrop (beans) production on land with agronomic and vegetative measures - one hectare

	Trash lines		Grass strips		Contour tillage + planting		Contour ridging	
	Qty	Value	Qty	Value	Qty	Value	Qty	Value
Labour								
-Labour land preparation (days)	37	6918	18	2954	36	6722	16	2711
-Labour others (days)	201	29,707	95	12,655	181	24,238	99	13,261
Sub-total	*238*	*36,625*	*113*	*15,609*	*217*	*30,960*	*115*	*15,972*
Materials								
-Maize seeds (kg)	35	6292	12	2196	46	9645	16	3014
-Beans seeds (kg)	48	8278	23	2331	21	3022	18	2058
Manure (wheelbarrows)	6	316	16	745	51	1673	18	924
Basal fertilisers (kg)	115	7187	69	4393	50	2777	56	3338
Topdressing fertilisers (kg)	31	1915	43	2514	35	1894	22	1267
Pesticides (lump sum)		4719		224		6791		639
Sub-total		*28,707*		*12,403*		*25,802*		*11,240*
Total		65,332		28,012		56,762		27,212

Qty = Quantity; Values are in KSh ha^{-1}.

3.5.4 **Benefits of agronomic and vegetative SWC measures**

The benefits of structural SWC measures were considered as an increase in crop yields grown in the conserved land area while costs include costs of production of grains and construction of the SWC measures. The costs and benefits were used in gross margin analysis (Table 41). The 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 41
Grain yields and gross margins per hectare achieved with SWC structural measures

	Trash lines		Grass strips		Contour planting + tillage		Contour ridging	
Description	Qty	Value	Qty	Value	Qty	Value	Qty	Value
Maize grain yields (kg/ha)	2112	54,385	980	20,853	1852	36,986	1675	41,165
Beans grain yields (kg/ha)	25	1729	336	22,775	139	8035	114	8447
Sub-total		*56,116*		*43,628*		*45,021*		*49,612*
Crop residues (KSh)		*89,101*		*13,431*		*40,257*		*10,757*
Napier grass (FM kg/ha)			248992	528,728	188,937	328,072		0
		145,217		585,787				
Gross income						85,278		60,369
Maize/beans-production costs		65,332		28,012		56,761		27,211
Napier grass-production costs		0		105,955		0		0
Establishment cost of Structure		0		94,190		0		0
Annual maintenance cost of structure		16,935		24,300		0		0
Total costs		82,267		146,502		56,761		27,211
Total labour-days	261		252		217		115	
Gross margins (GM)		62,950		439,285		28,517		33,158
BCR (undiscounted)		2		4		2		2
GM/Labour-day		241		1743		131		288

Qty = Quantity; Values are in KSh ha^{-1}; BCR = benefit-cost ratio.

3.5.5 **Financial cost benefit analysis of agronomic and vegetative SWC measures**

The incremental net benefits and costs were discounted over a period of 15 years using different discount rates (Annexes 11-14). The NPV and BCR attained indicate that the SWC measures were viable. However, for contour tillage + planting it is the BCR calculated based on incremental net benefits (INB) at different discount rates (10%, 12% and 14%) that reached a value of one (see Annex 13-Scenario 2). The results show that the SWC structures studied will begin to pay in financial terms in the same year one of establishment (Table 42).

Table 42
Financial efficiency of studied SWC structural measures (15-year time horizon; values for NPV and INB x 1000)

	Discount rate	Trash lines	Grass strips	Contour tillage + Planting	Contour ridging
Time elapse after base year*		<1	<1	<1	<1
NPV	10%	526.5	3962.7	214.9	250.2
	12%	589.9	3538.6	192.3	223.9
	14%	473.1	3181.9	173.4	201.9
BCR (discounted)	10%	1.1	8.0	0.5	1.2
	12%	1.1	7.8	0.5	1.2
	14%	1.1	7.6	0.5	1.2
IRR (%)		471	566		
INB	10%	589.5	3980.8	356.1	252.1
	12%	523.5	3553.7	317.3	224.7
	14%	468.2	3194.7	284.9	201.7

*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 and IRR = Internal Rate of Return.

The NPV and BCR values for grass strips (napier grass strips) are 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. This is an important observation to be considered in the design of Commercial Sustainable Investment Package for GWC.

3.6 Focus group discussions on conservation of rangeland areas

3.6.1 **Background**

Rangelands were understood in this study as those lands which are predominantly used for livestock in parts of semi-humid to semi-arid areas (ACZ IV), and semi-arid (ACZ V) and arid areas (ACZ VI). Degradation of rangelands is most noticeable in ACZ IV and V where human and livestock densities are relatively high and involve loss of soil productivity and vegetation as well as deterioration of water resources (Thomas *et al.* 1997). Rangeland deterioration is associated with loss of ground cover, surface sealing, soil erosion (water and wind erosion), sedimentation of reservoirs and loss of trees and shrubs among other factors. The immediate causes of rangeland deterioration include continuous grazing and tracking around water points, loss of ground cover due to heavy grazing, drought and termite activity, indiscriminate cutting of trees for charcoal and uncontrolled burning of vegetation among others.

3.6.2 **Focus group discussions with farmers in the rangelands**

Focus group discussions held in Mbeere North District and in Tharaka South District in the rangeland areas near the Mutonga and Tana rivers respectively investigated types of soil and water conservation practices adopted in the rangelands, service providers on conservation practices in the rangelands, farmers perceived benefits of soil and water conservation and challenges of implementing soil and water conservation practices in addition to grazing management. The outputs of the discussions are presented in Boxes 1-2.

Box 2

Focus group discussions with Nkuuni/Kithukioni food-for-asset (FFA) group in Kamanyaki location, Tharaka south Division

The focus group discussion (FDG) was carried out on 2nd June 2011 with 17 members (10 male, 7 female) of Nkuuni /Kithukioni FFA group in Kamanyakini location, Tharaka south Division. The group is registered with the Social Services Department as an FFA. The group is involved in farming activities which include soil and water conservation measures geared towards harvesting of water and for more efficient water utilisation in micro-irrigation sites.

Soil and Water Conservation practices adopted in rangelands

The group identified the following SWC practices in the rangelands:

- Semi-circular bunds for planting grass
- Negarims
- *Zai* pits
- Stone lines
- *Fanya juu* and *Fanya chini*
- Check dams
- Controlled grazing to address overgrazing problems
- Tree planting
- Napier grass, sugar cane, grass along river.

Benefits of SWC

The Group perceived the following as benefits of SWC:

- Conservation of moisture resulting in increased production;
- Prevention of soil loss;
- Prevention of loss of soil fertility; and
- *Zai* pits are good for tree planting.

Challenges of implementing SWC practices

The group outlined the following as challenges for implementing SWC in the rangelands:

- Dry area with difficult soils;
- Inadequate tools for constructing SWC measures (crowbar);
- Famine hinders labour.
- Lack of community common action on how to address overgrazing

The group saw the following as an **opportunity** for addressing the above challenges:

- Longer period of land preparation;
- Group effort through self-help income generation activities; and
- Irrigation for food production.

Investment costs for soil and water conservation practices in the rangelands

Discussions were held with the farmers on the type of investments they incurred when constructing soil and water conservation practices. For construction of a **semi-circular bund** (length 40 metres) covering a quarter of an acre the following costs are incurred:

(a) Lay-out costs: One levelling board (KSh 300-500); One spirit level (KSh700); 20-30 pegs (KSH 5.00 per piece); String (KSh 150-300); Labour for 6 persons for one hour each (KSh 200 per person day)

(b) Establishment costs:
  - Equipment: one wheelbarrow (KSh 4000); one spade (KSh500); one fork *jembe* (KSh 1700); one mattock (KSh 1300); one hammer (KSh 500-800); one *jembe* (KSh 750).
  - Labour for digging; one person for 90 days @ KSh 200 per day
  - Grass (Nthendu, Kiutha, Ndemantigwa, Rugoka) KSh 2000
  - Labour for planting grass: 5 man days @ KSh 200 per day.

(c) Maintenance costs (annual): Replanting (gap filling) twice a year; Labour only -3 man-days @ KSh 200 per day.

Benefits for SWC in the rangelands

The perceived benefits from 0.25 acre constructed with a semi-circular bund under grass were as follows:

- Grazing of animals: Investment cost plus profit would be KSh 10,000 – 20,000. The grass would reach its peak twice in a year. The grass would be grazed for 2 months by 5 cattle. Households with both cattle and goats can graze the grass for 2

months while households with goats only (15-20 goats) can graze between 5 and 6 months.
- Other benefits would accrue from sale of animals: Average sale of livestock was estimated as follows: Zebu bulls/oxen (KSH30, 000-35,000 during good season and KSh 18,000-20,000 during dry season); Zebu cows (KSh 10,000-15,000); zebu heifers (KSh 15,000); Zebu calves (KSh 10,000-12,000).
- Sale of milk; It was reported that the average milk production per cow per day was 1-2 litres during the peak season and usually 1 litre for most of the time with an average lactation period of 8 months.

Stone bunds
Stone bunds are also used in the rangelands. From discussions with the group it was reported that the investment costs required for a stone bund of 70 metres are as follows:
- Lay-out costs: Equipment (Levelling board, spirit level, string, pegs) and labour for 3 persons for 20 minutes @ KSh 200 per person day of 5 hours.
- Establishment costs: 600 wheelbarrows of stones: Labour per day handling 9 wheelbarrows of stones equivalent to 5 metres of stone bund. The spacing between stone bunds was estimated as 20 metres. Other costs were 1kg of seeds planted in 0.25 acre and manure applied by placement method.

Benefits
The perceived benefits were the yields of millet estimated at 2 bags per 0.25 acre and stover used for feeding cattle

Inventory of Service Providers
The group identified the following organisations as service providers in their area:
- Catholic Diocese of Meru (FBO);
- Government organizations: MKEPP, Ministry of Agriculture (MoA), Ministry of Livestock Development (MoLD) and Kenya Forest Service (KFS)
- World Food Programme (WFP)
- People Living with HIV and AIDS (PLWHA)

Using pairwise ranking the group ranked the service providers as follows:
1. Catholic Diocese
2. MoA , MoLD and WFP
3. PLWHA
4. KFS

Box 3

Focus Group Discussions with Farmers in Nthigirani Village, Kamarandi Location, Evurore Division, Mbeere North District

The Focus Group Discussion (FDG) was carried out on 3rd June 2011 with 15 farmers (10 male, 5 female) at Nthigirani Village, Kamarandi Location, Evurore Division. The farmers involved in the discussions had their farms located in the vicinity of Mutonga River. The farmers are involved in soil and water conservation activities in their farms where they grow crops (mainly sorghum, millet and pulses-green grams, pigeon pea) and keeping of livestock (cattle and shoats). The farmers use group effort in establishing soil and water conservation practices.

Soil and Water Conservation Practices adopted in Rangelands

The group identified the following SWC practices in the rangeland:

- Stone lines
- Trash lines
- *Fanya juu* terraces
- Contour ploughing
- Riverine protection
- Fencing (for regeneration of vegetation)
- Grass strips for stabilization of structures.

Benefits of SWC

The Group perceived the following as benefits of SWC:

- Increase in production due to moisture conservation
- Higher/increased yields
- Prevention of soil loss
- Accumulation of overwash (sediment)
- Maintenance of soil fertility

Challenges of implementing SWC practices

The group outlined the following as challenges for implementing SWC in the rangelands:

- Drought leading to famine and hence affects labour availability
- Inadequate and inappropriate tools
- No water for irrigation
- Access to labour (low incomes)
- Low technical know how
- No follow-up after training

The group saw the following as **opportunities** for addressing the above challenges:

- Facilitate access to water for irrigation; relief food and food for work;
- Provision of appropriate tools. This could be done through “merry-go-round” (a reciprocal savings club);
- Access to capacity building plus trainings and seminars; and
- Refresher training and monitoring.

Investment costs for soil and water conservation practices in the rangelands

Discussions were held on the costs incurred by farmers during preparation and construction of soil and water conservation measures in the rangelands. Fencing of the rangelands for rehabilitation and regeneration was selected as a case study. The areas which are usually fenced range from 0.81 to 2.02 hectares (1.2 hectares average). The group gave the following costs:

(a) Lay-out costs: None

(b) Establishment costs:
   - Equipment: *Panga* 2No. @ KSh 350 each; Forked stick (*mwirigi*) 5No. @ KSh 100; File 4No. @ KSh 150.
   - Labour: 14 man days (5 hours per day) @ KSh 200 per day

(c) Maintenance costs: Only labour equivalent to 7 man days per year @ KSh 200 per day.

Benefits for SWC in the rangelands

The group perceived the benefits of fencing of approximately 1.2 ha as conservation of grass which can be used for grazing of livestock. The grass in the enclosed area at its peak period can be sold for grazing at KSh 3000-5000. The grass in such enclosed area can reach its peak twice a year but in most cases it is once a year. A typical household in the area has 5-20 cattle and 30 goats.

The grass in the enclosed area can be grazed for 3 months by a household with 5 cattle before the grass runs out. A household with 30 goats can graze for 6 months while household with both cattle and goats can graze for one month.
Other benefits would accrue from sale of livestock as follows: Zebu bulls/oxen (KSh 15,000-25,000); Zebu cows (KSh 13,000-15,000); Zebu heifers (KSh 8000); Zebu calves (KSh 6000).
The average milk production per cow per day was reported as 5 glasses (one milking per day only). The sale of milk is KSh 10 per glass (4 milk glasses = 1 litre). The lactation period is about 8 months.

Inventory of Service Providers
The group identified the following organisations as the service provider in the area:
- Ministry of Agriculture (MoA);
- MKEPP
- Catholic Diocese
- Care International
- Ministry of Livestock Development (MoLD)

Using pairwise ranking the group ranked the service providers as follows:
1. MKEPP
2. MoA and MoLD
3. Catholic Diocese
4. Care International

Overgrazing by livestock has caused serious soil erosion in the area. Prior to the advent of land adjudication in the studied rangelands, land was mainly held under communal tenure arrangements i.e. by a larger social unit with use rights granted to individuals or households; and pre-adjudication grazing involved negotiation and cooperation to determine grazing access of households and groups of households (Smucker 2002).

Currently there is a move towards individualised land rights in the studied areas through the process of adjudication, a series of legal processes intended to bring about the individualisation of land rights. The process begins with boundary demarcation and ends with a final adjudication of rights over individual parcels. The adjudication process in the rangelands studied has been very slow and incomplete in part, though increasingly most households have demarcated land boundaries (customary or otherwise) and or registered land parcels but without title deeds or security of tenure. It is estimated that about 75-80% of households in Tharaka do not have titles to their land (ALRMP 2005). The demarcation of land boundaries has not yet completely negated secondary land use rights for grazing uncultivated land, thus overgrazing is still a challenge. However, there is no clear structure (or community rules) for enforcing maximum herd sizes against available pasture. The establishment of such structures would incur costs of:
– Holding community meetings
– Community sensitisation campaigns and access to advice
– Building community structures (and agreeing on rules) to control overgrazing

The primary implication of the adjudication for livestock-keeping has been the loss of common grazing lands; and the grazing of miniscule public parcels, roadside vegetation, stream banks, and hillsides are certainly not sufficient as an adaptation to the restrictions of individualised tenure. This has led to some individual households renting grazing lands, borrowing or surreptitious grazing on the parcels of other households during drought periods.

3.6.3 Discussions with extension service providers in the rangelands

Discussions were held with the Ministry of Agriculture staff in the rangelands concerning soil and water conservation practices, challenges of rangeland management and on the potential role the Ministry of

Agriculture can play in GWC. A summary of these discussion outputs are presented in Boxes 3-4 while an analysis of strengths and weaknesses of the Ministry of Agriculture (and NALEP) in relation to participation in Green Water Credits is presented in Green Water Credits Report No. 16[8].

Box 4

Discussions with Ministry of Agriculture staff, Tharaka South Division

Discussions were held with the District Agricultural Extension Officer (Mr Paul Kaburu Nteere) and the District Agribusiness Officer (Mr, Jamleck Mutegi) on soil and water conservation in the rangelands. It was reported that the SWC practices in the area were the following:

- *Fanya juu* terraces
- Stone lines
- Grass strips
- Trash lines
- Retention ditches
- Fencing of grazing lands

The following were challenges to SWC in the rangelands:

- SWC is capital intensive- particularly with regard to; labour
- Land tenure system (Land adjudication is being done)
- Uncontrolled grazing system leading to trampling on SWC structures after harvests. In addition uncontrolled grazing also diminishes the vegetative cover of the grazing lands.
- Burning
- Cultivation on steep slopes
- Uncontrolled grazing is affecting tree planting. Tree seedlings eaten by livestock

The Ministry of Agriculture extension staff assists farmers with the lay-out of SWC measures. The Ministry has also trained community markers who charge KSh 100 per day for lay-out of SWC measures irrespective of the length or area of the terrace (no hidden costs to be paid). It was mentioned that the major issue of concern is trampling of SWC structures by livestock after harvest, thus destroying the structures.

Strengths

The strengths of MoA were outlined as follows:

- Trained and skilled staff on soil and water conservation
- Farmers groups are in place and hence there are linkages.

Potential role in GWC

- Training of farmers and community markers
- Supervision and monitoring of implementation of SWC measures

[8] Muchena F and Onduru D 2011. Institutes for Implementation of Green Water Credits in the Upper Tana, Kenya. Green Water Credits Report 16, ISRIC-World Soil Information

Box 5
Discussions with Ministry of Agriculture staff, Evurore Division, Mbeere North District

Discussions were held with the Divisional Agricultural Extension Officer (Mr Kinyua Njeru), Agricultural Business Development Officer (Samwel Njeru) and Area Frontline Extension Officer (Peter Kinyua). Evurore Division covers about 287.1 km^2 and Kamarandi location covers 88.2 km^2. The Location is predominantly a livestock and millet zone. The main issues in the area are:
- Land tenure system (Tharakas occupy the land but owners are Mbeere).
- Environmental issues- charcoal production is the main distress coping mechanism and a major source of income. MKEPP through Ministry of Agriculture and Kenya Forest Service have been promoting tree planting.
- Drought. The Catholic Diocese has been carrying out drought mitigation activities such as water harvesting. The Diocese has also constructed water pans.

Soil and Water Conservation practices in the area are:
- *Fanya juu*
- Stone lines
- Hill conservation (no grazing and no cultivation)
- Fencing for regeneration of vegetation. MKEPP has carried out demonstrations on reseeding but have not been successful due to drought for three consecutive years.

Challenges
- Land tenure issues
- Small staff to farmer ratio
- Uptake of trees is low due to damage by livestock

Strengths
The perceived strength of MoA was:
- Technical skills
- Well-endowed with issues of community mobilisation

Potential role in GWC
- Community mobilisation and training
- Technical assistance, e.g. contour line pegging

A summary of the strengths, weaknesses, opportunities and threats faced by the Ministry of Agriculture is presented in Box 6. The strengths of the Ministry of Agriculture is in skilled manpower on soil and water conservation and their geographical coverage and institutional organisation that ensures that extension services reaches every location in the country. The Ministry of Agriculture provides extension services to farmer groups based on a demand driven approach, however, during this study it was noted that challenges exist in terms:
– Staffing for some of the districts
– Mobility of staff
– Slow response from some farmers in accessing demand-driven services and to apply for technical and financial assistance; thus sensitisation and awareness creation till need to be created on services offered and some of the projects run by the Ministry.

Today the small-scale farmers in Kenya are facing a number of risks and their profitability is at stake: low prices of farm outputs, high prices of seed and other inputs, declining soil fertility and land degradation, and decreasing farm sizes due to fragmentation and increase in population. This has partly contributed to farmer’s limited capacity to invest.

Box 6
SWOT Analysis of the Ministry of Agriculture, Kenya

Strengths
- Skilled manpower
- A well-structured extension services
- Dynamic and committed political leadership
- Committed, dynamic and competent workforce
- Institutional capacity and policy arrangements
- Government commitment to enhance funding to the sector
- Improved financial management system
- Public/Private Partnerships
- A growing private sector driven value-chain
- Responsive and strong farming community
- Availability of arable land
- Well established research institutions and Farmer Training Centres
- Adequate infrastructure in horticulture sub-sector (handling facilities & transport)

Weaknesses
- Poor governance and accountability in key institutions
- Poor succession management
- Inadequate and unevenly distributed workforce
- Rigid and bureaucratic procurement process
- Weak and unfavourable legal and regulatory environment
- Duplication and overlapping of roles by several institutions and stakeholders
- Lack of capital and access to affordable credit
- Under-funding of the agricultural sector
- Low and declining land fertility
- High cost and increased adulteration of key farm inputs
- Inability to produce competitively
- Weak information management
- Inadequate land management and environmental conservation
- Weak research-extension linkages
- Poor infrastructure
- Over-reliance on rainfed production
- Lack of sufficient agricultural market information

Opportunities
- A vibrant democratic leadership from grassroots to the national levels
- Staff rationalisation; Motivation scheme institutionalised
- Increased level of stakeholder participation
- Collaboration within and outside productive sector ministries
- Willing donor community
- To harness potential of partnerships through appropriate policy
- Ready and growing regional and global markets
- Niche markets arising from organic farming
- Diversified climatic conditions
- Unexploited skills and expertise in the Ministry
- Building farmer groups participation
- Dynamic technological development and innovations

Threats
- Unpredictable mergers and split in ministries including transfer of functions
- Corruption
- High staff turn-over
- Poverty and unemployment
- Threat from HIV-AIDS
- Conflicting policies
- Government restriction on recruitment of technical staff
- Non-tariff barriers to trade
- Lack of land use policy
- Unpredictable donor funding
- Unfavourable macro-economic environment
- High prevalence of pests and diseases
- Unpredictable weather conditions; Natural catastrophes

4 Discussions and over-arching remarks

The study addresses the costs and benefits of soil and water conservation measures in a temporal perspective. It analyses the investment and annual costs, and benefits of soil and water conservation practices accruing in the present and in the future over a period of 15 years. The returns to investment on soil and water conservation technologies were determined using several financial calculations, such as Net Present Value, benefit-cost ratio, Internal Rate of Return and Incremental Net Benefits. All calculations and indicators used are based on 2011 prices, the year when the study was realised. The following main conclusions and observations emerge from the study:

Conclusion 1: The 14 practices were profitable in the agro-ecological zones covered:
(i) Microcatchments with bananas
- Investment costs and annual maintenance costs were KSh 197,150 ha^{-1} and KSh 39, 900 ha^{-1} respectively;
- About 79% of labour demand for producing bananas in microcatchments was required during the establishment phase;
- The conservation practice is viable as the benefit-cost ratios was positive and greater than one at different discount rates used in the study (10-14%); and
- The conservation practice is worth investing in as the Internal Rate of Return was higher than the market interest rates (10%-14%).

(ii) Mulching in tea
- Mulching in tea is profitable with gross margins being positive, a benefit-cost ratio (undiscounted) higher than one and gross margins per labour-day higher than opportunity costs;
- Labour is the major cost item incurred by farmers in tea maintenance. It accounts for about 70% of annual labour demand for tea maintenance; and
- This conservation practice is viable and profitable to invest in as the benefit-cost ratio was positive and greater than one and the internal rate of return higher than market interest rates.

(iii) Zero tillage in coffee
- This conservation practice is viable, because the gross margins were positive and the undiscounted benefit-cost ratio was also higher than one; and
- The practice was also worth investing in since the internal rate of return was higher than prevailing market interest rate. However, the discounted benefit-cost ratio is envisaged to increase with improvement in coffee prices.

(iv) Riverine protection
- Riverine protection - when using a mix of fast growing fodder grasses and trees-has a positive Net Present Value, one year after the year of establishment. This is due to the high value fodder grasses as trees take long to bring returns; and
- This conservation practice is viable, because the benefit-cost ratio was higher than one. The practice is also worth investing in, because the Internal Rate of Return was higher than the cost of capital (market interest rates).

(iv) SWC structural measures
- Structural measures studied include bench terraces, *fanya juu* terraces, cut-off drains, retention/ infiltration ditches and stone lines;

- The average costs of laying out the SWC structures comprises labour and materials and equipment such as line level (levelling board+ string + spirit level), pegs, string and *pangas*. This cost to the farmer is a non-cash cost since government agricultural extension officers provide the equipment for lay-out and also the expertise without farmers paying for them;
- Substantial costs in establishing SWC structures are labour and materials. Labour cost for establishing the structures with grass stabiliser accounted for 43%, 38% and 38% of total investment costs for bench terraces, cut-off drains, and infiltration ditches respectively. These figures were 36% and 31% for *fanya juu* and stone lines respectively;
- The Net Profit Value 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. However, it is to be noted that the profitability of bench terraces, as it was other types of terraces, depends on management level of the farmer and whether high value crops have been grown on conserved land and on the structures embankments and risers; and
- The structural SWC practices studied are financially attractive to farmers as the benefit-cost ratios were higher than one and the Internal Rate of Return was also higher than the cost of capital (market interest rate).

(v) Agronomic and vegetative SWC measures
- Agronomic and vegetative measures studied include trash lines, grass strips, contour tillage + planting (contour farming) and contour ridging;
- 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 lay-out and establishment;
- The agronomic and vegetative measures studied are viable because of a Benefit-cost Ratio higher than one and Internal Rate of Return higher than the prevailing market interest rate (cost of capital);
- The results show that the SWC structures studied will begin to pay-off in financial terms in the same year of establishment; and
- The Net Profit Value and benefit-cost ratio values for grass strips (napier grass strips) were higher than the rest of the agronomic and vegetative 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 within a short time period.

Conclusion 2: Smallholders ability to invest in the structures is limited in the short-term due to limited availability of capital. Small-scale credit schemes, labour sharing groups and stepwise construction of the SWC measures can overcome the high investment costs. The initial high cost of conservation is mainly in the form of labour and materials.

Conclusion 3: Farmers consider unutilised land and or land occupied by conservation structures to be lost if no crop is planted on it. This study has shown that when high value fodder crops (especially napier grass) are planted to stabilise SWC structures in high rainfall areas, then the time period taken for the conservation structures to pay off is shortened to one-two years depending on the structure and that there are incremental gains when conserved land is planted with high value crops.

Conclusion 4: Our experiences from this study tend to show that there is need to combine structural measures which bring returns in the long-term with those that are profitable in the short term to address farmers' needs:
- Structural measures can be combined with agronomic and vegetative measures, for example, early planting, planting of fodder grass strips, quick maturing fodder and shrubs, use of contour ridges etc. to address farmers' needs in the short term but also in the long-term; and

- On-farm measures that can improve soil moisture and nutrient availability need to be implemented alongside SWC structures in an integrated way. This may include the use of organic and inorganic sources of fertility that can improve on productivity gains and thus makes SWC structures more profitable.

Conclusion 5: Profitability of conservation structures depend on prices of inputs and outputs, technologies used and farmer's level of management. However, economic 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 and inclusion of credit policies that enhance smallholders' access to inputs are required.

Conclusion 6: Despite the positive indicators of this cost-benefit study, the implementation of SWC practices is not automatically done by farmers, because a major hindrance for farmers is the time lag between investments and the return of the benefits.

Conclusion 7: There are capable Extension Service Providers in the Upper Tana catchment, e.g. the Ministry of Agriculture and others and thus farmers can be trained and technical assistance given. However, to support the needed large number of smallholders, farmers several challenges need to be met:
- The staff of the extension services need to be expanded;
- Means of transport for extension staff needs to be addressed, as it is currently inadequate; and
- SWC awareness and training actions should be accompanied by adequate incentives for the farmer to implement.

Conclusion 8: Main observations for the Commercial Sustainable Investment Package (CSIP) are:
- Because of the long time lag between investment and return of benefits, soft loans are needed to make farmers interested to invest in the long term SWC works;
- Farmers need support to develop an 'entrepreneurial' farm plan, e.g. introduce high value crops or livestock in the farm plan, in order to make the SWC practices attractive from investment perspective; this means a high Cost Benefit Ratio and high Net Present Value;
- Farmers need technical advice and support tailored to their farm and natural resources conditions; and
- To make the investments operational and effective, the farmers will require adequate institutional support, e.g. on how to apply for loans, technical assistance, cooperation between the several institutions etc.

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Annex 1 Formulae used to calculate cost-benefit analytical tools

(i) Net Present Value (Net Present Worth)

The NPV measures the present value of the stream of net benefits over the life span of the conservation practice. The NPV is the accumulated total of net benefits. For a soil conservation practice to be economically viable, the NPV must be positive (NPV > 0).

Net Present Value can be defined as:

$$NPV = \frac{\sum_{t=1}^{t=T} (B_t - C_t)}{(1+r)^t} > 0 \qquad (1a)$$

Where

$$B_t = \sum_{i=1}^{I} P_i Q_i \qquad (1b)$$

With Bt = Revenue of the SWC practice in time period t

P_1 = Price of output

Q_1 = Quantity of output

And

$$C_t = \sum_{j}^{J} P_j R_j \qquad (1c)$$

With Ct =Cost of the SWC in time period t

P_j = Price of output

Q_j = Quantity of output

(ii) Internal (Financial) Rate of Return (IRR)

IRR is the maximum interest rate that a project (e.g. SWC) could pay for the resources used if the project is to recover its investment and operating costs and still break-even (Gittinger 1982). It is the discount rate that makes the present value of net benefit stream (undiscounted) or cash flow stream (undiscounted) equal to zero (*i.e.* NPV=0). This essentially means that IRR is the rate of return that makes the sum of present value of future net benefits or cash flow stream and the final market value of a project (or an investment) equals its current market value. IRR thus computes the break-even rate of return. When the NPV is equal to zero, then the IRR is equal to the discount rate. When IRR exceeds the cost of capital (interest rate farmers pay on loan), then the SWC structure is worth investing in; IRR can be defined as:

$$IRR = \sum_{t=1}^{T} \frac{B_t}{(1+r)^t} = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} \quad (2)$$

Where: r is the discount rate

(iii) Benefit-cost ratio (BCR)

The value of benefit-cost ratio (BCR) shows the returns that one Kenya Shilling invested in the SWC practice will bring to the user in present value terms. The formal decision criteria is to accept a SWC practice with a ratio of one or greater. If the BCR were less than 1, present worth of costs at a specific discount rate would exceed present worth of benefits and initial expenditure would thus not be recovered and the SWC practice would not be profitable. BCR (discounted) can be defined as:

$$BCR = \frac{\sum_{t=1}^{T} \frac{B_t}{(1+r)^t}}{\sum_{t=}^{T} \frac{C_t}{(1+r)^t}} > 1 \quad (3)$$

In addition to the BRC (discounted) above, the study also calculated undicounted BCR in the year of the study: (4)

BCR (undiscounted) = $B_t/C_t \geq 2$

In the literature, two scenarios to calculation of financial CBA have been reported (i) determination of net benefits and costs of conservation practice without making comparison with the "without" plot (*in situ comparison*); and (ii) modelling net benefits and costs of conservation as the difference between farm plots "with" and farm plots "without" conservation structure (paired plots). Both scenarios have been used in calculations in this report enabling readers to compare results with similar work elsewhere in literature. The two scenarios are described below:

a) Scenario 1

The benefits of conservation were considered to be increased crop yields grown in the conserved land and yields of grasses and other materials or crops used in stabilising conservation practices. In Scenario 1, the net benefits of conservation practice was determined *in situ* (without making comparison with the "without" plot) by considering the difference between streams of benefits and costs incurred over a given time horizon for the particular practice (Thomas *et al.* 1997). The streams of costs and benefits were used to calculate NPV, BCR and IRR as appropriate. NPV was calculated as defined in equation 1(a) while IRR and BCR were calculated as presented in equations 2, 3 and 4.

b) Scenario 2 (Incremental Net Benefits)

This view considers the benefits/returns to SWC structure as the difference in net benefits between farm plots "with" and "without" conservation structure where farm plots "with" and "without" SWC structure are paired and are assumed to be in the vicinity of each other and same agro-ecological conditions. Assuming climate, management practices and other related factors that influence crop yields remain constant over the time horizon of the study, the differences in yield and returns to investment between the "with" and "without" soil conservation situation can be attributed to the presence or absence of SWC structure in farmers cultivated fields. In this scenario, the net benefits of the situation "with" and "without" practice are calculated and the difference between the "with" and "without" situation gives the Incremental net benefit (INB) of conservation practice.

The Net Benefit (NB_1) with farm plots "with" conservation practice in time *t* can be defined as:

$$NB_1 = PQ_t^{swc-st} - C_t^{est} - C_t^{swc-stmc} - C_t^{swc-structure} \qquad (5)$$

Where:

PQ_t^{swc-st}	=	Gross revenue from stabiliser grasses planted on SWC structure risers and embankments in year *t*
C_t^{est}	=	Establishment cost of stabiliser materials in year *t*
$C_t^{swc-stmc}$	=	Maintenance cost of stabiliser material in year *t*
$C_{t_0}^{swc-structure}$	=	Establishment cost of physical SWC structure in year t_o

The Net Benefit π_t^{E} with farm plots "without" conservation practice in time *t* can be defined as:

$$\pi_t^E = PY_t^E - C^E Y_t^E \qquad (6)$$

π_t^E	=	Net benefit in year *t* for farm plots without SWC practice
Py_t^E	=	Crop yield (*Y*) in year *t* in farm plots without SWC practice multiplied by price of crop products (gross revenue)
$C^E Y_t^E$	=	Corresponding annual cost of production

(iv) Incremental Net Benefits

The Incremental Net Benefit (INB_T) of SWC practice in year *t* (discounted) was defined as:

$$NB_t = \sum_{t=1}^{T} \frac{(NB_1 - NB_2)}{(1+r)^t} \qquad (7)$$

With $(1 + r)^t$ = discount rate

Annex 2 Annual costs and net benefit flows of microcatchments with bananas

Year		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	NPV	Total cost discounte	BCR	IRR	PVoA-NB	Pvoa-Costs
With micro-catchment																							
	Investment costs (Ksh)	191,650																					
	Tools and others (contigency)	5500	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550						
	Maintenance costs (Ksh)	0	3990	3990	3990	3990	3990	3990	3990	3990	3990	3990	3990	3990	3990	3990	3990						
	Total costs (Ksh)	**197,150**	**4,540**	**4,540**	**4,540**	**4,540**	**4,540**	**4,540**	**4,540**	**4,540**	**4,540**	**4,540**	**4,540**	**4,540**	**4,540**	**4,540**	**4,540**						
	Total labour-days	378	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81						
	Banana-bunches (MT)	0	2.8	5.5	8.3	11	10.5	9.9	9.4	9.0	8.5	8.1	7.7	7.3	6.9	6.6	6.6						
	Gross value-bunches (Ksh)	0	46065	92130	138194	184259	175046	166294	157979	150080	142576	135447	128675	122241	116129	110323	110323						
	Banana-pseudo-stems (No)	0	125	251	376	501	476	452	430	408	388	368	350	332	316	300	285						
	Gross value-pseudostems (Ksh)	0	2380	4760	7139	9519	9043	8591	8161	7753	7366	6997	6647	6315	5999	5699	5414						
	Net benefit (NB1)	**(197,150)**	**43,905**	**92,349**	**140,794**	**189,238**	**179,549**	**170,345**	**161,601**	**153,294**	**145,402**	**137,905**	**130,783**	**124,016**	**117,589**	**111,482**	**111,197**				53%		
Scenario 1	12% discount factor	1	0.8929	0.7972	0.7118	0.6355	0.5674	0.5066	0.4523	0.4039	0.3606	0.322	0.2875	0.2567	0.2292	0.2046	1.2046						
	NPV (at 12% rate)	(197,150)	39,202	73,621	100,217	120,261	101,876	86,297	73,092	61,915	52,432	44,405	37,600	31,835	26,951	22,809	133,948						
	Cumulative NPV1	**(197,150)**	**(157,948)**	**(84,327)**	**15,890**	**136,151**	**238,027**	**324,324**	**397,416**	**459,331**	**511,763**	**556,168**	**593,768**	**625,603**	**652,555**	**675,364**	**809,312**						
Rate 1	**12%**																	695,684	228,071	3.1		102143	33486
Rate 2	**10%**																	806,423	231,682	3.5		106023	30460
Rate 3	**14%**																	602,067	225,035	2.7		98022	36638
Without micro-catchment																							
	Investment costs (Ksh)	130,160																					
	Tools and others (contigency)	5500	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550						
	Maintenance costs (Ksh)	0	885	885	885	885	885	885	885	885	885	885	885	885	885	885	885						
	Total costs (Ksh)	**135,660**	**1,435**	**1,435**	**1,435**	**1,435**	**1,435**	**1,435**	**1,435**	**1,435**	**1,435**	**1,435**	**1,435**	**1,435**	**1,435**	**1,435**	**1,435**						
	Total labour-days	334	59	59	59	59	59	59	59	59	59	59	59	59	59	59	59						
	Banana yields (MT)	0	1.7	3.3	5.0	6.6	5.9	5.2	4.7	4.1	3.7	3.3	2.9	2.6	2.3	2.1	1.8						
	Gross value (Ksh)	0	27639	55278	82917	110556	98394	87571	77938	69365	61735	54944	48900	43521	38734	34473	30681						
	Banana-pseudo-stems (No)	0	75	150	225	301	268	238	212	189	168	149	133	118	105	94	83						
	Gross value-pseudostems (Ksh)	0	1428	2856	4284	5711	5083	4524	4026	3583	3189	2838	2526	2248	2001	1781	1585						
	Net benefit (NB2)	**(135,660)**	**27,632**	**56,698**	**85,765**	**114,832**	**102,043**	**90,660**	**80,530**	**71,513**	**63,489**	**56,347**	**49,991**	**44,335**	**39,300**	**34,819**	**30,831**						
Scenario 2	*Benefits of SWC practice*																						
	NB_T (NB1-NB2)	(61,490)	16,273	35,651	55,028	74,406	77,507	79,685	81,071	81,780	81,913	81,557	80,791	79,682	78,289	76,663	80,366				65%		
	NPV (at 12% rate)	(61,490)	14,530	28,421	39,169	47,285	43,977	40,368	36,668	33,031	29,538	26,261	23,227	20,454	17,944	15,685	96,809						
	ANPV	**(61,490)**	**(46,960)**	**(18,539)**	**20,630**	**67,915**	**111,892**	**152,261**	**188,929**	**221,960**	**251,498**	**277,759**	**300,987**	**321,441**	**339,385**	**355,070**	**451,879**						
Rate 1	**12%**																	369,754	228,071	1.6		54,289	33,486
Rate 2	**10%**																	429,783	231,682	1.9		56,505	30,460
Rate 3	**14%**																	319,640	225,035	1.4		52,040	36,638

NB: Net Benefits NPV: Net Present value ANPV: Accumulative Net Present Value BCR: Benefit cost ratio IRR: Internal Rate of Return PVoA-NB: Net benefit ordinary annuity PVoA-Costs: Cost ordinary Annuit

Annex 3 Annual costs and net benefit flows of mulching in tea

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	NPV	Total cost discounte	BCR	IRR	PVoA-NB	Pvoa-Costs
Investment costs (Ksh)	85,050	46105	46105	46105	46105	46105																
Tools and others (contigency)	1054	1054	1054	1054	1054	1054	216	216	216	216	216	216	216	216	216	216						
Maintenance costs (Ksh)	0	0	0	0	0	0	105388	105388	105388	105388	105388	105388	105388	105388	105388	105388						
Total costs (Ksh)	**86,104**	**47,159**	**47,159**	**47,159**	**47,159**	**47,159**	**105,604**	**105,604**	**105,604**	**105,604**	**105,604**	**105,604**	**105,604**	**105,604**	**105,604**	**105,604**						
Total labour-days	171	150	150	150	150	150	458	458	458	458	458	458	458	458	458	458						
Tea green leaf yields (MT)	0	0.0	0	0.0	0	0.0	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8						
Gross value-yields (Ksh)	0	0	0	0	0	0	361963	361963	361963	361963	361963	361963	361963	361963	361963	361963						
Other yields (kg)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0						
Gross value-other yields (Ksh)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0						
Net benefit (NB1)	**(86,104)**	**(47,159)**	**(47,159)**	**(47,159)**	**(47,159)**	**(47,159)**	**256,359**	**256,359**	**256,359**	**256,359**	**256,359**	**256,359**	**256,359**	**256,359**	**256,359**	**256,359**				31%		
12% discount factor	1	0.8929	0.7972	0.7118	0.6355	0.5674	0.5066	0.4523	0.4039	0.3606	0.322	0.2875	0.2567	0.2292	0.2046	0.1827						
NPV (at 12% rate)	(86,104)	(42,108)	(37,595)	(33,568)	(29,970)	(26,758)	129,871	115,951	103,543	92,443	82,548	73,703	65,807	58,757	52,451	46,837						
Cumulative NPV1	**(86,104)**	**(128,212)**	**(165,807)**	**(199,375)**	**(229,345)**	**(256,103)**	**(126,231)**	**(10,280)**	**93,263**	**185,706**	**268,254**	**341,957**	**407,764**	**466,522**	**518,973**	**565,810**						
12%																	565,808	594,677	1.0		$83,074	$87,313
10%																	713,211	667,784	1.1		$93,768	$87,796
14%																	446,494	534,095	0.8		$72,693	$86,955
Investment costs (Ksh)	85,050	42665	42665	42665	42665	42665																
Tools and others (contigency)	1054	1054	1054	1054	1054	1054	216	216	216	216	216	216	216	216	216	216						
Maintenance costs (Ksh)	0	0	0	0	0	0	108828	108828	108828	108828	108828	108828	108828	108828	108828	108828						
Total costs (Ksh)	**86,104**	**43,719**	**43,719**	**43,719**	**43,719**	**43,719**	**109,044**	**109,044**	**109,044**	**109,044**	**109,044**	**109,044**	**109,044**	**109,044**	**109,044**	**109,044**						
Total labour-days	171	127	127	127	127	127	450	450	450	450	450	450	450	450	450	450						
Tea green leaf yields (MT)	0	0.0	0.0	0.0	0.0	0.0	6.3	6.2	6.1	6.1	6.0	6.0	5.9	5.8	5.8	5.7						
Gross value-yields (Ksh)	0	0	0	0	0	0	289570	286675	283808	280970	278160	275379	272625	269898	267199	264528						
Other yields (kg)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0						
Gross value-other yields (Ksh)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0						
Net benefit (NB2)	**(86,104)**	**(43,719)**	**(43,719)**	**(43,719)**	**(43,719)**	**(43,719)**	**180,526**	**177,631**	**174,764**	**171,926**	**169,116**	**166,335**	**163,581**	**160,854**	**158,155**	**155,484**				25%		
Benefits of SWC practice																						
NB_T (NB1-NB2)	-	(3,440)	(3,440)	(3,440)	(3,440)	(3,440)	75,833	78,728	81,595	84,433	87,243	90,024	92,778	95,504	98,203	100,875				89%		
NPV (at 12% rate)	-	(3,072)	(2,742)	(2,449)	(2,186)	(1,952)	38,417	35,609	32,956	30,447	28,092	25,882	23,816	21,890	20,092	18,430						
ANPV	**-**	**(3,072)**	**(5,814)**	**(8,263)**	**(10,449)**	**(12,401)**	**26,016**	**61,625**	**94,581**	**125,028**	**153,120**	**179,002**	**202,818**	**224,708**	**244,800**	**263,230**						
12%																	263,228	594,677	0.4		$38,648	$87,313
10%																	316,462	667,784	0.5		$41,606	$87,796
14%																	220,065	534,095	0.4		$35,829	$86,955

ANPV: Accumulative Net Present Value BCR: Benefit cost ratio IRR: Internal Rate of Return PVoA-NB: Net benefit ordinary annuity PVoA-Costs: Cost ordinary Annui

Annex 4 Annual costs and net benefit flows of zero-tillage in coffee

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	NPV	Total cost discounted	BCR	IRR	PVoA-NB	Pvoa-Costs
Investment costs (Ksh)	126,194																					
Tools and others (contigency)	591	591	591	591	591	591	591	591	591	591	591	591	591	591	591	591						
Maintenance costs (Ksh)	7529	82376	82376	82376	82376	82376	82376	82376	82376	82376	82376	82376	82376	82376	82376	82376						
Total costs (Ksh)	**134,314**	**82,967**	**82,967**	**82,967**	**82,967**	**82,967**	**82,967**	**82,967**	**82,967**	**82,967**	**82,967**	**82,967**	**82,967**	**82,967**	**82,967**	**82,967**						
Total labour-days	331	319	319	319	319	319	319	319	319	319	319	319	319	319	319	319						
Coffee cherry (MT)	0	0	0	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6						
Gross value-yields (Ksh)	0	0	0	212350	212350	212350	212350	212350	212350	212350	212350	212350	212350	212350	212350	212350						
Other yields (kg)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0						
Gross value-other yields (Ksh)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0						
Net benefit (NB1)	**(134,314)**	**(82,967)**	**(82,967)**	**129,383**	**129,383**	**129,383**	**129,383**	**129,383**	**129,383**	**129,383**	**129,383**	**129,383**	**129,383**	**129,383**	**129,383**	**129,383**				30%		
12% discount factor	1	0.8929	0.7972	0.7118	0.6355	0.5674	0.5066	0.4523	0.4039	0.3606	0.322	0.2875	0.2567	0.2292	0.2046	0.1827						
NPV (at 12% rate)	(134,314)	(74,081)	(66,141)	92,095	82,223	73,412	65,546	58,520	52,258	46,656	41,661	37,198	33,213	29,655	26,472	23,638						
Cumulative NPV1	**(134,314)**	**(208,395)**	**(274,537)**	**(182,441)**	**(100,218)**	**(26,806)**	**38,739**	**97,260**	**149,518**	**196,173**	**237,835**	**275,032**	**308,245**	**337,900**	**364,372**	**388,010**						
12%																	388,016	699,391	1		56,970	102,688
10%																	481,244	765,368	1		63,271	100,626
14%																	310,712	643,911	0.5		50,587	104,835
Investment costs (Ksh)	120,473																					
Tools and others (contigency)	591	591	591	591	591	591	591	591	591	591	591	591	591	591	591	591						
Maintenance costs (Ksh)	0	107801	107801	107801	107801	107801	107801	107801	107801	107801	107801	107801	107801	107801	107801	107801						
Total costs (Ksh)	**121,064**	**108,392**	**108,392**	**108,392**	**108,392**	**108,392**	**108,392**	**108,392**	**108,392**	**108,392**	**108,392**	**108,392**	**108,392**	**108,392**	**108,392**	**108,392**						
Total labour-days	331	475	475	475	475	475	475	475	475	475	475	475	475	475	475	475						
Coffee cherry (MT)	0	0.0	0.0	2.7	2.6	2.6	2.5	2.5	2.4	2.4	2.3	2.3	2.2	2.2	2.2	2.1						
Gross value-yields (Ksh)	0	0	0	159263	156078	152956	149897	146899	143961	141082	138260	135495	132785	130129	127527	124976						
Other yields (kg)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0						
Gross value-other yields (Ksh)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0						
Net benefit (NB2)	**(121,064)**	**(108,392)**	**(108,392)**	**50,871**	**47,686**	**44,564**	**41,505**	**38,507**	**35,569**	**32,690**	**29,868**	**27,103**	**24,393**	**21,737**	**19,135**	**16,584**				4%		
Benefits of SWC practice																						
NB_1(NB1-NB2)	(13,250)	25,425	25,425	78,513	81,698	84,819	87,879	90,876	93,814	96,694	99,515	102,280	104,990	107,646	110,249	112,799						
NPV (at 12% rate)	(13,250)	22,702	20,269	55,885	51,919	48,127	44,519	41,103	37,892	34,868	32,044	29,406	26,951	24,672	22,557	20,608						
ANPV	**(13,250)**	**(81,282)**	**(184,110)**	**795,331**	**1,839,973**	**2,942,302**	**4,095,645**	**5,294,070**	**6,532,342**	**7,805,765**	**9,110,210**	**10,441,987**	**11,797,828**	**13,174,833**	**14,570,409**	**15,982,292**						
12%																	500,271	699,391	1		73,452	102,688
10%																	574,228	765,368	1		75,496	100,626
14%																	438,856	643,911	1		71,450	104,835

ANPV: Accumulative Net Present Value BCR: Benefit cost ratio IRR: Internal Rate of Return PVoA-NB: Net benefit ordinary annuity PVoA-Costs: Cost ordinary Annuity

Annex 5 Annual costs and net benefit flows of riverine protection

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	NPV	Total cost discounted	BCR	IRR	PVoA-NB	Pvoa-Costs
Investment costs (Ksh)	38,333																					
Tools and others (contigency)	385	385	385	385	385	385	385	385	385	385	385	385	385	385	385	385						
Maintenance costs (Ksh)	8,533	8,533	8,533	8,533	8,533	8,533	8,533	8,533	8,533	8,533	8,533	8,533	8,533	8,533	8,533	8,533						
Total costs (Ksh)	**47,251**	**8,918**	**8,918**	**8,918**	**8,918**	**8,918**	**8,918**	**8,918**	**8,918**	**8,918**	**8,918**	**8,918**	**8,918**	**8,918**	**8,918**	**8,918**						
Total labour-days	174	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14						
Fodder grasses (Ksh)	0	266875	266875	266875	266875	266875	266875	266875	266875	266875	266875	266875	266875	266875	266875	266875						
Poles (Ksh)	0	0	0	0.0	0.0	0.0	11340	11340	11340	11340	11340	11340	11340	11340	11340	11340						
Fuelwood (Ksh)	0	0	0	0.0	0.0	0.0	20622	20622	20622	20622	20622	20622	20622	20622	20622	20622						
Trees/poles for timber (Ksh)	0	0	0	0	0	0	34719	34719	34719	34719	34719	34719	34719	34719	34719	34719						
Other yields (kg)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0						
Gross value-other yields (Ksh)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0						
Net benefit (NB1)	**(47,251)**	**257,957**	**257,957**	**257,957**	**257,957**	**257,957**	**324,638**	**324,638**	**324,638**	**324,638**	**324,638**	**324,638**	**324,638**	**324,638**	**324,638**	**324,638**				546%		
12% discount factor	1	0.8929	0.7972	0.7118	0.6355	0.5674	0.5066	0.4523	0.4039	0.3606	0.322	0.2875	0.2567	0.2292	0.2046	0.1827						
NPV (at 12% rate)	(47,251)	230,330	205,643	183,614	163,932	146,365	164,462	146,834	131,121	117,064	104,533	93,333	83,335	74,407	66,421	59,311						
Cumulative NPV1	**(47,251)**	**183,079**	**388,722**	**572,336**	**736,268**	**882,632**	**1,047,094**	**1,193,928**	**1,325,049**	**1,442,114**	**1,546,647**	**1,639,980**	**1,723,315**	**1,797,722**	**1,864,143**	**1,923,454**						
12%																	1,923,444	107,990	17.8		282,408	15,856
10%																	2,169,198	115,082	18.8		285,193	15,130
14%																	1,717,809	102,027	16.8		279,675	16,611

Annex 6 Annual costs and net benefit flows for bench terraces

Bench terrace with maize and beans crops

Year		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	NPV	Total cost	BCR	IRR	PVoA-NB	Pvoa-Costs
With Bench terraces																							
	Investment costs (Ksh)	140,784																					
	Materials, tools and others (conti	3035	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202						
	Maintenance costs (Ksh)	0	33000	33000	33000	33000	33000	33000	33000	33000	33000	33000	33000	33000	33000	33000	33000						
	Annual cost-maize beans	0	251,121	251,121	251,121	251,121	251,121	251,121	251,121	251,121	251,121	251,121	251,121	251,121	251,121	251,121	251,121						
	Total costs (Ksh)	**143,819**	**284,323**	**284,323**	**284,323**	**284,323**	**284,323**	**284,323**	**284,323**	**284,323**	**284,323**	**284,323**	**284,323**	**284,323**	**284,323**	**284,323**	**284,323**						
	Grains (maize/beans) Ksh	0	75941	75941	75941	75941	75941	75941	75941	75941	75941	75941	75941	75941	75941	75941	75941						
	Maize/beans residues (Ksh)	0	30346	30346	30346	30346	30346	30346	30346	30346	30346	30346	30346	30346	30346	30346	30346						
	Napier (Ksh)	0	461189	461189	461189	461189	461189	461189	461189	461189	461189	461189	461189	461189	461189	461189	461189						
	Net benefit (NB1)	**(143,819)**	**283,153**	**283,153**	**283,153**	**283,153**	**283,153**	**283,153**	**283,153**	**283,153**	**283,153**	**283,153**	**283,153**	**283,153**	**283,153**	**283,153**	**283,153**				197%		
Scenario 1	12% discount factor	1	0.8929	0.7972	0.7118	0.6355	0.5674	0.5066	0.4523	0.4039	0.3606	0.322	0.2875	0.2567	0.2292	0.2046	1.2046						
	NPV (at 12% rate)	(143,819)	252,827	225,729	201,548	179,944	160,661	143,445	128,070	114,365	102,105	91,175	81,406	72,685	64,899	57,933	341,086						
	Cumulative NPV1	**(143,819)**	**109,008**	**334,737**	**536,285**	**716,229**	**876,890**	**1,020,335**	**1,148,405**	**1,262,770**	**1,364,875**	**1,456,050**	**1,537,457**	**1,610,142**	**1,675,040**	**1,732,974**	**2,074,059**						
Rate 1	**12%**																	1,784,695	2,080,307	0.9		262037	305439
Rate 2	**10%**																	2,009,863	2,306,405	0.9		264244	303232
Rate 3	**14%**																	1,595,352	1,890,181	0.8		259738	307738
Without Bench terraces																							
	Investment costs (Ksh)	-																					
	Materials, tools and others (conti	0	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202						
	Maintenance costs (Ksh)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						
	Annual cost-maize beans	0	251121	251121	251121	251121	251121	251121	251121	251121	251121	251121	251121	251121	251121	251121	251121						
	Total costs (Ksh)	-	251,323	251,323	251,323	251,323	251,323	251,323	251,323	251,323	251,323	251,323	251,323	251,323	251,323	251,323	251,323						
	Grains (maize/beans) Ksh	0	37971	37211	36467	35738	35023	34322	33636	32963	32304	31658	31025	30404	29796	29200	28616						
	Maize/beans residues (Ksh)	0	15173	14870	14572	14281	13995	13715	13441	13172	12909	12650	12397	12149	11907	11668	11435						
	Napier (Ksh)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				#NUM!		
	Net benefit (NB1)	**-**	**(198,180)**	**(199,243)**	**(200,284)**	**(201,305)**	**(202,305)**	**(203,286)**	**(204,247)**	**(205,188)**	**(206,111)**	**(207,015)**	**(207,901)**	**(208,770)**	**(209,621)**	**(210,455)**	**(211,272)**						
Rate 1	**12%**																	(1,383,353)	1,711,729	-0.8		-203110	251323
Rate 2	**10%**																	(1,547,024)	1,911,585	-0.8		-203393	251323
Rate 3	**14%**																	(1,245,891)	1,543,670	-0.8		-202842	251323
Scenario 2	*Benefits of SWC practice*																						
	NB_T (NB1-NB2)	(143,819)	481,333	482,395	483,437	484,458	485,458	486,438	487,399	488,341	489,263	490,168	491,054	491,922	492,773	493,607	494,425				335%		
	NPV (at 12% rate)	(143,819)	429,782	384,566	344,110	307,873	275,449	246,430	220,451	197,241	176,428	157,834	141,178	126,276	112,944	100,992	595,584						
	ANPV	**(143,819)**	**285,963**	**670,528**	**1,014,639**	**1,322,512**	**1,597,961**	**1,844,390**	**2,064,841**	**2,262,082**	**2,438,510**	**2,596,344**	**2,737,522**	**2,863,799**	**2,976,742**	**3,077,735**	**3,673,319**						
Rate 1	**12%**																	3,168,049	2,080,307	1.5		465,146	305,439
Rate 2	**10%**																	3,556,887	2,306,405	1.5		467,637	303,232
Rate 3	**14%**																	2,841,243	1,890,181	1.5		462,580	307,738

NB: Net Benefits NPV: Net Present value ANPV: Accumulative Net Present Value BCR: Benefit cost ratio IRR: Internal Rate of Return PVoA-NB: Net benefit ordinary annuity PVoA-Costs: Cost ordinary Annuity

Annex 7 Annual costs and net benefit flows for *fanya juu* terraces

Fanya juu terrace with maize and beans crops

Year		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	NPV	Total cost	BCR	IRR	PVoA-NB	Pvoa-Costs
With Practice																							
	Investment costs (Ksh)	125,413																					
	Materials, tools and others (conti	3035	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202						
	Maintenance costs (Ksh)	0	30450	30450	30450	30450	30450	30450	30450	30450	30450	30450	30450	30450	30450	30450	30450						
	Annual cost-maize beans	0	164,004	164,004	164,004	164,004	164,004	164,004	164,004	164,004	164,004	164,004	164,004	164,004	164,004	164,004	164,004						
	Total costs (Ksh)	**128,448**	**194,656**	**194,656**	**194,656**	**194,656**	**194,656**	**194,656**	**194,656**	**194,656**	**194,656**	**194,656**	**194,656**	**194,656**	**194,656**	**194,656**	**194,656**						
	Grains (maize/beans) Ksh	0	59698	59698	59698	59698	59698	59698	59698	59698	59698	59698	59698	59698	59698	59698	59698						
	Maize/beans residues (Ksh)	0	25165	25165	25165	25165	25165	25165	25165	25165	25165	25165	25165	25165	25165	25165	25165						
	Napier (Ksh)	0	369167	369167	369167	369167	369167	369167	369167	369167	369167	369167	369167	369167	369167	369167	369167						
	Net benefit (NB1)	**(128,448)**	**259,374**	**259,374**	**259,374**	**259,374**	**259,374**	**259,374**	**259,374**	**259,374**	**259,374**	**259,374**	**259,374**	**259,374**	**259,374**	**259,374**	**259,374**				202%		
Scenario 1	12% discount factor	1	0.8929	0.7972	0.7118	0.6355	0.5674	0.5066	0.4523	0.4039	0.3606	0.322	0.2875	0.2567	0.2292	0.2046	1.2046						
	NPV (at 12% rate)	(128,448)	231,595	206,773	184,622	164,832	147,169	131,399	117,315	104,761	93,530	83,518	74,570	66,581	59,448	53,068	312,442						
	Cumulative NPV1	**(128,448)**	**103,147**	**309,919**	**494,542**	**659,374**	**806,542**	**937,941**	**1,055,256**	**1,160,017**	**1,253,547**	**1,337,065**	**1,411,635**	**1,478,216**	**1,537,665**	**1,590,733**	**1,903,174**						
Rate 1	**12%**																	1,638,111	1,454,226	1.1		240514	213516
Rate 2	**10%**																	1,844,369	1,609,020	1.1		242486	211544
Rate 3	**14%**																	1,464,669	1,324,060	1.1		238461	215569
Without practice																							
	Investment costs (Ksh)	-																					
	Materials, tools and others (conti	0	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202						
	Maintenance costs (Ksh)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						
	Annual cost-maize beans	0	164004	164004	164004	164004	164004	164004	164004	164004	164004	164004	164004	164004	164004	164004	164004						
	Total costs (Ksh)	-	164,206	164,206	164,206	164,206	164,206	164,206	164,206	164,206	164,206	164,206	164,206	164,206	164,206	164,206	164,206						
	Grains (maize/beans) Ksh	0	29849	29252	28667	28094	27532	26981	26442	25913	25394	24887	24389	23901	23423	22955	22495						
	Maize/beans residues (Ksh)	0	12583	12331	12084	11843	11606	11374	11146	10923	10705	10491	10281	10075	9874	9676	9483						
	Napier (Ksh)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				#NUM!		
	Net benefit (NB1)	-	**(121,775)**	**(122,623)**	**(123,455)**	**(124,270)**	**(125,069)**	**(125,852)**	**(126,619)**	**(127,370)**	**(128,107)**	**(128,829)**	**(129,537)**	**(130,230)**	**(130,910)**	**(131,576)**	**(132,228)**						
Rate 1	**12%**																	(856,201)	1,118,387	-0.8		-125711	164206
Rate 2	**10%**																	(957,889)	1,248,966	-0.8		-125937	164206
Rate 3	**14%**																	(770,826)	1,008,583	-0.8		-125497	164206
Scenario 2	*Benefits of SWC practice*																						
	NB_T (NB1-NB2)	(128,448)	381,149	381,997	382,829	383,644	384,443	385,225	385,992	386,744	387,481	388,203	388,910	389,604	390,283	390,949	391,602				297%		
	NPV (at 12% rate)	(128,448)	340,327	304,528	272,498	243,806	218,133	195,155	174,584	156,206	139,726	125,001	111,812	100,011	89,453	79,988	471,724						
	ANPV	**(128,448)**	**211,879**	**516,408**	**788,905**	**1,032,711**	**1,250,843**	**1,445,999**	**1,620,583**	**1,776,789**	**1,916,515**	**2,041,516**	**2,153,328**	**2,253,339**	**2,342,792**	**2,422,780**	**2,894,504**						
Rate 1	**12%**																	2,494,312	1,454,226	1.7		366,225	213,516
Rate 2	**10%**																	2,802,258	1,609,020	1.7		368,423	211,544
Rate 3	**14%**																	2,235,495	1,324,060	1.7		363,959	215,569

NB: Net Benefits NPV: Net Present value ANPV: Accumulative Net Present Value BCR: Benefit cost ratio IRR: Internal Rate of Return PVoA-NB: Net benefit ordinary annuity PVoA-Costs: Cost ordinary Annuity

Annex 8 Annual costs and net benefit flows for cut-off drains

Cut off Drain with maize and beans crops

Year		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	NPV	Total cost	BCR	IRR	PVoA-NB	Pvoa-Costs
With SWC practice																							
	Investment costs (Ksh)	130,255																					
	Materials, tools and others (conti	3035	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202						
	Maintenance costs (Ksh)	0	30150	30150	30150	30150	30150	30150	30150	30150	30150	30150	30150	30150	30150	30150	30150						
	Annual cost-maize beans	0	130,233	130,233	130,233	130,233	130,233	130,233	130,233	130,233	130,233	130,233	130,233	130,233	130,233	130,233	130,233						
	Total costs (Ksh)	**133,290**	**160,585**	**160,585**	**160,585**	**160,585**	**160,585**	**160,585**	**160,585**	**160,585**	**160,585**	**160,585**	**160,585**	**160,585**	**160,585**	**160,585**	**160,585**						
	Grains (maize/beans) Ksh	0	74467	74467	74467	74467	74467	74467	74467	74467	74467	74467	74467	74467	74467	74467	74467						
	Maize/beans residues (Ksh)	0	18591	18591	18591	18591	18591	18591	18591	18591	18591	18591	18591	18591	18591	18591	18591						
	Napier (Ksh)	0	328072	328072	328072	328072	328072	328072	328072	328072	328072	328072	328072	328072	328072	328072	328072						
	Net benefit (NB1)	**(133,290)**	**260,545**	**260,545**	**260,545**	**260,545**	**260,545**	**260,545**	**260,545**	**260,545**	**260,545**	**260,545**	**260,545**	**260,545**	**260,545**	**260,545**	**260,545**				195%		
Scenario 1	12% discount factor	1	0.8929	0.7972	0.7118	0.6355	0.5674	0.5066	0.4523	0.4039	0.3606	0.322	0.2875	0.2567	0.2292	0.2046	1.2046						
	NPV (at 12% rate)	(133,290)	232,640	207,706	185,456	165,576	147,833	131,992	117,844	105,234	93,952	83,895	74,907	66,882	59,717	53,307	313,852						
	Cumulative NPV1	**(133,290)**	**99,350**	**307,057**	**492,512**	**658,088**	**805,921**	**937,913**	**1,055,758**	**1,160,992**	**1,254,944**	**1,338,839**	**1,413,746**	**1,480,628**	**1,540,345**	**1,593,652**	**1,907,504**						
Rate 1	**12%**																	1,641,244	1,227,015	1.3		240974	180156
Rate 2	**10%**																	1,848,433	1,354,715	1.4		243021	178109
Rate 3	**14%**																	1,467,019	1,119,632	1.3		238844	182286
Without SWC practice																							
	Investment costs (Ksh)	-																					
	Materials, tools and others (conti	0	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202						
	Maintenance costs (Ksh)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						
	Annual cost-maize beans	0	130233	130233	130233	130233	130233	130233	130233	130233	130233	130233	130233	130233	130233	130233	130233						
	Total costs (Ksh)	-	130,435	130,435	130,435	130,435	130,435	130,435	130,435	130,435	130,435	130,435	130,435	130,435	130,435	130,435	130,435						
	Grains (maize/beans) Ksh	0	37234	36489	35759	35044	34343	33656	32983	32323	31677	31043	30422	29814	29218	28633	28061						
	Maize/beans residues (Ksh)	0	9296	9110	8927	8749	8574	8402	8234	8070	7908	7750	7595	7443	7294	7148	7005						
	Napier (Ksh)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				#NUM!		
	Net benefit (NB1)	-	**(83,906)**	**(84,837)**	**(85,749)**	**(86,643)**	**(87,518)**	**(88,377)**	**(89,218)**	**(90,042)**	**(90,850)**	**(91,642)**	**(92,418)**	**(93,178)**	**(93,923)**	**(94,653)**	**(95,369)**						
Rate 1	**12%**																	(600,873)	888,377	-0.7		-88223	130435
Rate 2	**10%**																	(672,916)	992,102	-0.7		-88471	130435
Rate 3	**14%**																	(540,439)	801,156	-0.7		-87988	130435
Scenario 2	*Benefits of SWC practice*																						
	NB_T (NB1-NB2)	(133,290)	344,451	345,382	346,294	347,187	348,063	348,921	349,763	350,587	351,395	352,187	352,962	353,723	354,468	355,198	355,914				259%		
	NPV (at 12% rate)	(133,290)	307,560	275,338	246,492	220,638	197,491	176,764	158,198	141,602	126,713	113,404	101,477	90,801	81,244	72,674	428,734						
	ANPV	**(133,290)**	**174,270**	**449,608**	**696,100**	**916,738**	**1,114,229**	**1,290,992**	**1,449,190**	**1,590,792**	**1,717,505**	**1,830,909**	**1,932,386**	**2,023,187**	**2,104,431**	**2,177,104**	**2,605,838**						
Rate 1	**12%**																	2,242,117	1,227,015	1.8		329,197	180,156
Rate 2	**10%**																	2,521,349	1,354,715	1.9		331,491	178,109
Rate 3	**14%**																	2,007,459	1,119,632	1.8		326,832	182,286

NB: Net Benefits NPV: Net Present value ANPV: Accumulative Net Present Value BCR: Benefit cost ratio IRR: Internal Rate of Return PVoA-NB: Net benefit ordinary annuity PVoA-Costs: Cost ordinary Annuity

Annex 9 Annual costs and net benefit flows for infiltration ditches

Infiltration Ditch with maize and beans crops

Year		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	NPV	Total cost	BCR	IRR	PVoA-NB	Pvoa-Costs
With SWC practice																							
	Investment costs (Ksh)	129,855																					
	Materials, tools and others (conti	3035	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202						
	Maintenance costs (Ksh)	0	35025	35025	35025	35025	35025	35025	35025	35025	35025	35025	35025	35025	35025	35025	35025						
	Annual cost-maize beans	0	137,797	137,797	137,797	137,797	137,797	137,797	137,797	137,797	137,797	137,797	137,797	137,797	137,797	137,797	137,797						
	Total costs (Ksh)	**132,890**	**173,024**	**173,024**	**173,024**	**173,024**	**173,024**	**173,024**	**173,024**	**173,024**	**173,024**	**173,024**	**173,024**	**173,024**	**173,024**	**173,024**	**173,024**						
	Grains (maize/beans) Ksh	0	51174	51174	51174	51174	51174	51174	51174	51174	51174	51174	51174	51174	51174	51174	51174						
	Maize/beans residues (Ksh)	0	22102	22102	22102	22102	22102	22102	22102	22102	22102	22102	22102	22102	22102	22102	22102						
	Napier (Ksh)	0	357360	357360	357360	357360	357360	357360	357360	357360	357360	357360	357360	357360	357360	357360	357360						
	Net benefit (NB1)	**(132,890)**	**257,612**	**257,612**	**257,612**	**257,612**	**257,612**	**257,612**	**257,612**	**257,612**	**257,612**	**257,612**	**257,612**	**257,612**	**257,612**	**257,612**	**257,612**				194%		
Scenario 1	12% discount factor	1	0.8929	0.7972	0.7118	0.6355	0.5674	0.5066	0.4523	0.4039	0.3606	0.322	0.2875	0.2567	0.2292	0.2046	1.2046						
	NPV (at 12% rate)	(132,890)	230,021	205,368	183,368	163,712	146,169	130,506	116,518	104,049	92,895	82,951	74,063	66,129	59,045	52,707	310,319						
	Cumulative NPV1	**(132,890)**	**97,131**	**302,499**	**485,867**	**649,580**	**795,749**	**926,255**	**1,042,772**	**1,146,822**	**1,239,716**	**1,322,667**	**1,396,731**	**1,462,860**	**1,521,904**	**1,574,612**	**1,884,931**						
Rate 1	**12%**																	1,621,668	1,311,335	1.2		238100	192536
Rate 2	**10%**																	1,826,525	1,448,927	1.3		240140	190496
Rate 3	**14%**																	1,449,404	1,195,635	1.2		235976	194660
Without SWC practice																							
	Investment costs (Ksh)	-																					
	Materials, tools and others (conti	0	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202						
	Maintenance costs (Ksh)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						
	Annual cost-maize beans	0	137797	137797	137797	137797	137797	137797	137797	137797	137797	137797	137797	137797	137797	137797	137797						
	Total costs (Ksh)	-	137,999	137,999	137,999	137,999	137,999	137,999	137,999	137,999	137,999	137,999	137,999	137,999	137,999	137,999	137,999						
	Grains (maize/beans) Ksh	0	25587	25075	24574	24082	23601	23129	22666	22213	21768	21333	20906	20488	20079	19677	19283						
	Maize/beans residues (Ksh)	0	11051	10830	10613	10401	10193	9989	9789	9594	9402	9214	9029	8849	8672	8498	8328						
	Napier (Ksh)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				#NUM!		
	Net benefit (NB1)	-	**(101,361)**	**(102,094)**	**(102,812)**	**(103,516)**	**(104,206)**	**(104,881)**	**(105,544)**	**(106,193)**	**(106,829)**	**(107,452)**	**(108,063)**	**(108,662)**	**(109,249)**	**(109,824)**	**(110,387)**						
Rate 1	**12%**																	(713,507)	939,895	-0.8		-104760	137999
Rate 2	**10%**																	(798,300)	1,049,634	-0.8		-104955	137999
Rate 3	**14%**																	(642,321)	847,615	-0.8		-104576	137999
Scenario 2	*Benefits of SWC practice*																						
	NB_T (NB1-NB2)	(132,890)	358,973	359,706	360,424	361,128	361,817	362,493	363,156	363,805	364,441	365,064	365,675	366,274	366,861	367,436	367,999				270%		
	NPV (at 12% rate)	(132,890)	320,527	286,757	256,550	229,497	205,295	183,639	164,255	146,941	131,417	117,551	105,132	94,022	84,084	75,177	443,292						
	ANPV	**(132,890)**	**187,637**	**474,394**	**730,944**	**960,441**	**1,165,736**	**1,349,375**	**1,513,630**	**1,660,571**	**1,791,988**	**1,909,539**	**2,014,670**	**2,108,693**	**2,192,777**	**2,267,955**	**2,711,246**						
Rate 1	**12%**																	2,335,175	1,311,335	1.8		342,860	192,536
Rate 2	**10%**																	2,624,824	1,448,927	1.8		345,096	190,496
Rate 3	**14%**																	2,091,725	1,195,635	1.7		340,552	194,660

NB: Net Benefits NPV: Net Present value ANPV: Accumulative Net Present Value BCR: Benefit cost ratio IRR: Internal Rate of Return PVoA-NB: Net benefit ordinary annuity PVoA-Costs: Cost ordinary Annuity

Annex 10 Annual costs and net benefit flows for stone lines

Stonelines with maize and beans crops

Year		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	NPV	Total cost	BCR	IRR	PVoA-NB	Pvoa-Costs
With SWC practice																							
	Investment costs (Ksh)	57,150																					
	Materials, tools and others (conti	1435	96	96	96	96	96	96	96	96	96	96	96	96	96	96	96						
	Maintenance costs (Ksh)	0	25800	25800	25800	25800	25800	25800	25800	25800	25800	25800	25800	25800	25800	25800	25800						
	Annual cost-maize beans	0	78,480	78,480	78,480	78,480	78,480	78,480	78,480	78,480	78,480	78,480	78,480	78,480	78,480	78,480	78,480						
	Total costs (Ksh)	**58,585**	**104,376**	**104,376**	**104,376**	**104,376**	**104,376**	**104,376**	**104,376**	**104,376**	**104,376**	**104,376**	**104,376**	**104,376**	**104,376**	**104,376**	**104,376**						
	Grains (maize/beans) Ksh	0	148378	148378	148378	148378	148378	148378	148378	148378	148378	148378	148378	148378	148378	148378	148378						
	Maize/beans residues (Ksh)	0	66729	66729	66729	66729	66729	66729	66729	66729	66729	66729	66729	66729	66729	66729	66729						
	Napier (Ksh)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0						
	Net benefit (NB1)	**(58,585)**	**110,731**	**110,731**	**110,731**	**110,731**	**110,731**	**110,731**	**110,731**	**110,731**	**110,731**	**110,731**	**110,731**	**110,731**	**110,731**	**110,731**	**110,731**				189%		
Scenario 1	12% discount factor	1	0.8929	0.7972	0.7118	0.6355	0.5674	0.5066	0.4523	0.4039	0.3606	0.322	0.2875	0.2567	0.2292	0.2046	1.2046						
	NPV (at 12% rate)	(58,585)	98,872	88,275	78,819	70,370	62,829	56,096	50,084	44,724	39,930	35,655	31,835	28,425	25,380	22,656	133,387						
	Cumulative NPV1	**(58,585)**	**40,287**	**128,562**	**207,381**	**277,750**	**340,579**	**396,676**	**446,760**	**491,484**	**531,414**	**567,069**	**598,904**	**627,329**	**652,709**	**675,364**	**808,751**						
Rate 1	**12%**																	695,591	769,474	1		102130	112977
Rate 2	**10%**																	783,646	852,475	1		103029	112078
Rate 3	**14%**																	621,545	699,678	1		101193	113914
Without SWC practice																							
	Investment costs (Ksh)	-																					
	Materials, tools and others (conti	0	96	96	96	96	96	96	96	96	96	96	96	96	96	96	96						
	Maintenance costs (Ksh)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						
	Annual cost-maize beans	0	78480	78480	78480	78480	78480	78480	78480	78480	78480	78480	78480	78480	78480	78480	78480						
	Total costs (Ksh)	-	78,576	78,576	78,576	78,576	78,576	78,576	78,576	78,576	78,576	78,576	78,576	78,576	78,576	78,576	78,576						
	Grains (maize/beans) Ksh	0	74189	72705	71251	69826	68430	67061	65720	64405	63117	61855	60618	59405	58217	57053	55912						
	Maize/beans residues (Ksh)	0	33365	32697	32043	31402	30774	30159	29556	28965	28385	27818	27261	26716	26182	25658	25145						
	Napier (Ksh)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				#NUM!		
	Net benefit (NB1)	**-**	**28,978**	**26,827**	**24,719**	**22,653**	**20,628**	**18,644**	**16,700**	**14,794**	**12,927**	**11,097**	**9,303**	**7,546**	**5,823**	**4,135**	**2,481**						
Rate 1	**12%**																	129,410	535,168	0.2		19000	78576
Rate 2	**10%**																	140,157	597,653	0.2		18427	78576
Rate 3	**14%**																	120,030	482,625	0.2		19542	78576
Scenario 2	*Benefits of SWC practice*																						
	NB_T (NB1-NB2)	(58,585)	81,754	83,905	86,013	88,079	90,103	92,087	94,032	95,937	97,804	99,635	101,428	103,186	104,908	106,596	108,250				142%		
	NPV (at 12% rate)	(58,585)	72,998	66,889	61,224	55,974	51,124	46,651	42,530	38,749	35,268	32,082	29,161	26,488	24,045	21,810	130,398						
	ANPV	**(58,585)**	**14,413**	**81,301**	**142,525**	**198,499**	**249,624**	**296,275**	**338,805**	**377,554**	**412,823**	**444,905**	**474,066**	**500,553**	**524,598**	**546,408**	**676,806**						
Rate 1	**12%**																	566,181	769,474	1		83,129	112,977
Rate 2	**10%**																	643,489	852,475	1		84,602	112,078
Rate 3	**14%**																	501,515	699,678	1		81,651	113,914

NB: Net Benefits NPV: Net Present value ANPV: Accumulative Net Present Value BCR: Benefit cost ratio IRR: Internal Rate of Return PVoA-NB: Net benefit ordinary annuity PVoA-Costs: Cost ordinary Annuity

Annex 11 Annual costs and net benefit flows for trash lines

Trashlines with maize and beans crops

Year		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	NPV	Total cost	BCR	IRR	PVoA-NB	Pvoa-Costs
With SWC practice																							
	Investment costs (Ksh)	15,500																					
	Materials, tools and others (conti	1435	96	96	96	96	96	96	96	96	96	96	96	96	96	96	96						
	Maintenance costs (Ksh)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0						
	Annual cost-maize beans	0	65,332	65,332	65,332	65,332	65,332	65,332	65,332	65,332	65,332	65,332	65,332	65,332	65,332	65,332	65,332						
	Total costs (Ksh)	**16,935**	**65,428**	**65,428**	**65,428**	**65,428**	**65,428**	**65,428**	**65,428**	**65,428**	**65,428**	**65,428**	**65,428**	**65,428**	**65,428**	**65,428**	**65,428**						
	Grains (maize/beans) Ksh	0	56116	56116	56116	56116	56116	56116	56116	56116	56116	56116	56116	56116	56116	56116	56116						
	Maize/beans residues (Ksh)	0	89101	89101	89101	89101	89101	89101	89101	89101	89101	89101	89101	89101	89101	89101	89101						
	Napier (Ksh)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0						
	Net benefit (NB1)	**(16,935)**	**79,789**	**79,789**	**79,789**	**79,789**	**79,789**	**79,789**	**79,789**	**79,789**	**79,789**	**79,789**	**79,789**	**79,789**	**79,789**	**79,789**	**79,789**				471%		
Scenario 1	12% discount factor	1	0.8929	0.7972	0.7118	0.6355	0.5674	0.5066	0.4523	0.4039	0.3606	0.322	0.2875	0.2567	0.2292	0.2046	1.2046						
	NPV (at 12% rate)	(16,935)	71,244	63,608	56,794	50,706	45,272	40,421	36,089	32,227	28,772	25,692	22,939	20,482	18,288	16,325	96,114						
	Cumulative NPV1	**(16,935)**	**54,309**	**117,917**	**174,711**	**225,417**	**270,690**	**311,111**	**347,200**	**379,426**	**408,199**	**433,891**	**456,830**	**477,312**	**495,600**	**511,925**	**608,039**						
Rate 1	**12%**																	526,499	462,554	1.1		77303	67914
Rate 2	**10%**																	589,949	514,583	1.1		77563	67654
Rate 3	**14%**																	473,144	418,803	1.1		77032	68185
Without SWC practice																							
	Investment costs (Ksh)	-																					
	Materials, tools and others (conti	0	96	96	96	96	96	96	96	96	96	96	96	96	96	96	96						
	Maintenance costs (Ksh)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						
	Annual cost-maize beans	0	65332	65332	65332	65332	65332	65332	65332	65332	65332	65332	65332	65332	65332	65332	65332						
	Total costs (Ksh)	-	65,428	65,428	65,428	65,428	65,428	65,428	65,428	65,428	65,428	65,428	65,428	65,428	65,428	65,428	65,428						
	Grains (maize/beans) Ksh	0	28058	27497	26947	26408	25880	25362	24855	24358	23871	23393	22925	22467	22018	21577	21146						
	Maize/beans residues (Ksh)	0	44551	43659	42786	41931	41092	40270	39465	38675	37902	37144	36401	35673	34960	34260	33575						
	Napier (Ksh)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				10%		
	Net benefit (NB1)	**-**	**7,181**	**5,729**	**4,306**	**2,911**	**1,544**	**205**	**(1,108)**	**(2,394)**	**(3,655)**	**(4,890)**	**(6,101)**	**(7,288)**	**(8,451)**	**(9,590)**	**(10,707)**						
Rate 1	**12%**																	3,032	445,619	0.0		445	65428
Rate 2	**10%**																	442	497,648	0.0		58	65428
Rate 3	**14%**																	4,980	401,868	0.0		811	65428
Scenario 2	*Benefits of SWC practice*																						
	NB_T (NB1-NB2)	(16,935)	72,609	74,061	75,484	76,878	78,245	79,585	80,897	82,184	83,444	84,680	85,891	87,077	88,240	89,379	90,496				431%		
	NPV (at 12% rate)	(16,935)	64,832	59,041	53,729	48,856	44,396	40,318	36,590	33,194	30,090	27,267	24,694	22,353	20,225	18,287	109,012						
	ANPV	**(16,935)**	**47,897**	**106,938**	**160,668**	**209,524**	**253,920**	**294,238**	**330,828**	**364,022**	**394,112**	**421,379**	**446,072**	**468,425**	**488,649**	**506,937**	**615,948**						
Rate 1	**12%**																	523,467	462,554	1.1		76,858	67,914
Rate 2	**10%**																	589,507	514,583	1.1		77,505	67,654
Rate 3	**14%**																	468,165	418,803	1.1		76,221	68,185

NB: Net Benefits NPV: Net Present value ANPV: Accumulative Net Present Value BCR: Benefit cost ratio IRR: Internal Rate of Return PVoA-NB: Net benefit ordinary annuity PVoA-Costs: Cost ordinary Annuity

Annex 12 Annual costs and net benefit flows for grass strips

Napier grass strips with maize and beans crops

Year		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	NPV	Total cost	BCR	IRR	PVoA-NB	Pvoa-Costs
With SWC practice																							
	Investment costs (Ksh)	92,755																					
	Materials, tools and others (conti	1435	96	96	96	96	96	96	96	96	96	96	96	96	96	96	96						
	Maintenance costs (Ksh)	0	24300	24300	24300	24300	24300	24300	24300	24300	24300	24300	24300	24300	24300	24300	24300						
	Annual cost-maize beans	0	28,012	28,012	28,012	28,012	28,012	28,012	28,012	28,012	28,012	28,012	28,012	28,012	28,012	28,012	28,012						
	Total costs (Ksh)	**94,190**	**52,408**	**52,408**	**52,408**	**52,408**	**52,408**	**52,408**	**52,408**	**52,408**	**52,408**	**52,408**	**52,408**	**52,408**	**52,408**	**52,408**	**52,408**						
	Grains (maize/beans) Ksh	0	43628	43628	43628	43628	43628	43628	43628	43628	43628	43628	43628	43628	43628	43628	43628						
	Maize/beans residues (Ksh)	0	13431	13431	13431	13431	13431	13431	13431	13431	13431	13431	13431	13431	13431	13431	13431						
	Napier (Ksh)	0	528728	528728	528728	528728	528728	528728	528728	528728	528728	528728	528728	528728	528728	528728	528728						
	Net benefit (NB1)	**(94,190)**	**533,379**	**533,379**	**533,379**	**533,379**	**533,379**	**533,379**	**533,379**	**533,379**	**533,379**	**533,379**	**533,379**	**533,379**	**533,379**	**533,379**	**533,379**				566%		
Scenario 1	12% discount factor	1	0.8929	0.7972	0.7118	0.6355	0.5674	0.5066	0.4523	0.4039	0.3606	0.322	0.2875	0.2567	0.2292	0.2046	1.2046						
	NPV (at 12% rate)	(94,190)	476,254	425,210	379,659	338,963	302,639	270,210	241,247	215,432	192,337	171,748	153,347	136,918	122,251	109,129	642,509						
	Cumulative NPV1	**(94,190)**	**382,064**	**807,274**	**1,186,934**	**1,525,896**	**1,828,536**	**2,098,746**	**2,339,993**	**2,555,425**	**2,747,762**	**2,919,510**	**3,072,856**	**3,209,775**	**3,332,025**	**3,441,155**	**4,083,664**						
Rate 1	**12%**																	3,538,584	451,132	7.8		519550	66237
Rate 2	**10%**																	3,962,736	492,807	8.0		520996	64791
Rate 3	**14%**																	3,181,915	416,087	7.6		518044	67743
Without SWC practice																							
	Investment costs (Ksh)	-																					
	Materials, tools and others (conti	0	96	96	96	96	96	96	96	96	96	96	96	96	96	96	96						
	Maintenance costs (Ksh)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						
	Annual cost-maize beans	0	28012	28012	28012	28012	28012	28012	28012	28012	28012	28012	28012	28012	28012	28012	28012						
	Total costs (Ksh)	-	28,108	28,108	28,108	28,108	28,108	28,108	28,108	28,108	28,108	28,108	28,108	28,108	28,108	28,108	28,108						
	Grains (maize/beans) Ksh	0	21814	21378	20950	20531	20121	19718	19324	18937	18559	18187	17824	17467	17118	16775	16440						
	Maize/beans residues (Ksh)	0	6716	6581	6450	6321	6194	6070	5949	5830	5713	5599	5487	5377	5270	5164	5061						
	Napier (Ksh)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				133%		
	Net benefit (NB1)	**-**	**422**	**(149)**	**(708)**	**(1,256)**	**(1,793)**	**(2,319)**	**(2,835)**	**(3,340)**	**(3,836)**	**(4,321)**	**(4,797)**	**(5,263)**	**(5,720)**	**(6,168)**	**(6,607)**						
Rate 1	**12%**																	(15,152)	191,438	-0.1		-2225	28108
Rate 2	**10%**																	(18,079)	213,789	-0.1		-2377	28108
Rate 3	**14%**																	(12,782)	172,642	-0.1		-2081	28108
Scenario 2	*Benefits of SWC practice*																						
	NB_T (NB1-NB2)	(94,190)	532,958	533,528	534,087	534,635	535,172	535,699	536,214	536,720	537,215	537,701	538,176	538,643	539,099	539,547	539,986				566%		
	NPV (at 12% rate)	(94,190)	475,878	425,329	380,163	339,761	303,657	271,385	242,530	216,781	193,720	173,140	154,726	138,270	123,562	110,391	650,467						
	ANPV	**(94,190)**	**381,688**	**807,016**	**1,187,180**	**1,526,940**	**1,830,597**	**2,101,982**	**2,344,512**	**2,561,293**	**2,755,013**	**2,928,152**	**3,082,878**	**3,221,148**	**3,344,709**	**3,455,100**	**4,105,568**						
Rate 1	**12%**																	3,553,737	451,132	7.9		521,775	66,237
Rate 2	**10%**																	3,980,814	492,807	8.1		523,373	64,791
Rate 3	**14%**																	3,194,698	416,087	7.7		520,125	67,743

NB: Net Benefits NPV: Net Present value ANPV: Accumulative Net Present Value BCR: Benefit cost ratio IRR: Internal Rate of Return PVoA-NB: Net benefit ordinary annuity PVoA-Costs: Cost ordinary Annuity

Annex 13 Annual costs and net benefit flows for contour tillage + planting

Contour tillage + planting with maize and beans crops

Year		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	NPV	Total cost	BCR	IRR	PVoA-NB	Pvoa-Costs
With SWC practice																							
	Investment costs (Ksh)	-																					
	Materials, tools and others (conti	0	1435	103	103	103	103	103	103	103	103	103	103	103	103	103	103						
	Maintenance costs (Ksh)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0						
	Annual cost-maize beans	0	56,762	56,762	56,762	56,762	56,762	56,762	56,762	56,762	56,762	56,762	56,762	56,762	56,762	56,762	56,762						
	Total costs (Ksh)	-	**58,197**	**56,865**	**56,865**	**56,865**	**56,865**	**56,865**	**56,865**	**56,865**	**56,865**	**56,865**	**56,865**	**56,865**	**56,865**	**56,865**	**56,865**						
	Grains (maize/beans) Ksh	0	45021	45021	45021	45021	45021	45021	45021	45021	45021	45021	45021	45021	45021	45021	45021						
	Maize/beans residues (Ksh)	0	40257	40257	40257	40257	40257	40257	40257	40257	40257	40257	40257	40257	40257	40257	40257						
	Napier (Ksh)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0						
	Net benefit (NB1)	-	**27,081**	**28,414**	**28,414**	**28,414**	**28,414**	**28,414**	**28,414**	**28,414**	**28,414**	**28,414**	**28,414**	**28,414**	**28,414**	**28,414**	**28,414**				#NUM!		
Scenario 1	12% discount factor	1	0.8929	0.7972	0.7118	0.6355	0.5674	0.5066	0.4523	0.4039	0.3606	0.322	0.2875	0.2567	0.2292	0.2046	1.2046						
	NPV (at 12% rate)	-	24,181	22,651	20,225	18,057	16,122	14,394	12,851	11,476	10,246	9,149	8,169	7,294	6,512	5,813	34,227						
	Cumulative NPV1	-	**24,181**	**46,832**	**67,057**	**85,113**	**101,235**	**115,629**	**128,481**	**139,957**	**150,203**	**159,352**	**167,521**	**174,815**	**181,327**	**187,141**	**221,367**						
Rate 1	**12%**																	192,331	388,486	0.5		28239	57039
Rate 2	**10%**																	214,904	433,727	0.5		28254	57024
Rate 3	**14%**																	173,352	350,440	0.5		28223	57055
Without SWC practice																							
	Investment costs (Ksh)	-																					
	Materials, tools and others (conti	0	1435	103	103	103	103	103	103	103	103	103	103	103	103	103	103						
	Maintenance costs (Ksh)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						
	Annual cost-maize beans	0	56762	56762	56762	56762	56762	56762	56762	56762	56762	56762	56762	56762	56762	56762	56762						
	Total costs (Ksh)	-	58,197	56,865	56,865	56,865	56,865	56,865	56,865	56,865	56,865	56,865	56,865	56,865	56,865	56,865	56,865						
	Grains (maize/beans) Ksh	0	22511	22060	21619	21187	20763	20348	19941	19542	19151	18768	18393	18025	17664	17311	16965						
	Maize/beans residues (Ksh)	0	20129	19726	19331	18945	18566	18195	17831	17474	17125	16782	16446	16118	15795	15479	15170						
	Napier (Ksh)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				#NUM!		
	Net benefit (NB1)	-	**(15,558)**	**(15,078)**	**(15,914)**	**(16,733)**	**(17,536)**	**(18,322)**	**(19,093)**	**(19,848)**	**(20,589)**	**(21,314)**	**(22,025)**	**(22,722)**	**(23,405)**	**(24,074)**	**(24,730)**						
Rate 1	**12%**																	(125,018)	388,486	-0.3		-18356	57039
Rate 2	**10%**																	(141,226)	433,727	-0.3		-18568	57024
Rate 3	**14%**																	(111,521)	350,440	-0.3		-18157	57055
Scenario 2	*Benefits of SWC practice*																						
	NB_T (NB1-NB2)	-	42,639	43,492	44,328	45,147	45,949	46,736	47,507	48,262	49,002	49,728	50,439	51,136	51,818	52,488	53,143				#NUM!		
	NPV (at 12% rate)	-	38,072	34,672	31,552	28,691	26,072	23,676	21,487	19,493	17,670	16,012	14,501	13,127	11,877	10,739	64,017						
	ANPV	-	**38,072**	**72,744**	**104,296**	**132,987**	**159,058**	**182,735**	**204,222**	**223,715**	**241,385**	**257,398**	**271,899**	**285,025**	**296,902**	**307,641**	**371,658**						
Rate 1	**12%**																	317,349	388,486	1		46,594	57,039
Rate 2	**10%**																	356,130	433,727	1		46,822	57,024
Rate 3	**14%**																	284,872	350,440	1		46,380	57,055

NB: Net Benefits NPV: Net Present value ANPV: Accumulative Net Present Value BCR: Benefit cost ratio IRR: Internal Rate of Return PVoA-NB: Net benefit ordinary annuity PVoA-Costs: Cost ordinary Annuity

Annex 14 Annual costs and net benefit flows for contour ridging

Ridging with maize and beans crops

	Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	NPV	Total cost	BCR	IRR	PVoA-NB	Pvoa-Costs
With SWC practice																							
	Investment costs (Ksh)	-																					
	Materials, tools and others (conti	0	1435	103	103	103	103	103	103	103	103	103	103	103	103	103	103						
	Maintenance costs (Ksh)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0						
	Annual cost-maize beans	0	27,212	27,212	27,212	27,212	27,212	27,212	27,212	27,212	27,212	27,212	27,212	27,212	27,212	27,212	27,212						
	Total costs (Ksh)	**-**	**28,647**	**27,315**	**27,315**	**27,315**	**27,315**	**27,315**	**27,315**	**27,315**	**27,315**	**27,315**	**27,315**	**27,315**	**27,315**	**27,315**	**27,315**						
	Grains (maize/beans) Ksh	0	49612	49612	49612	49612	49612	49612	49612	49612	49612	49612	49612	49612	49612	49612	49612						
	Maize/beans residues (Ksh)	0	10757	10757	10757	10757	10757	10757	10757	10757	10757	10757	10757	10757	10757	10757	10757						
	Napier (Ksh)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0						
	Net benefit (NB1)	**-**	**31,722**	**33,055**	**33,055**	**33,055**	**33,055**	**33,055**	**33,055**	**33,055**	**33,055**	**33,055**	**33,055**	**33,055**	**33,055**	**33,055**	**33,055**				#NUM!		
Scenario 1	12% discount factor	1	0.8929	0.7972	0.7118	0.6355	0.5674	0.5066	0.4523	0.4039	0.3606	0.322	0.2875	0.2567	0.2292	0.2046	1.2046						
	NPV (at 12% rate)	-	28,325	26,351	23,528	21,006	18,755	16,745	14,951	13,351	11,919	10,644	9,503	8,485	7,576	6,763	39,817						
	Cumulative NPV1	**-**	**28,325**	**54,676**	**78,204**	**99,210**	**117,965**	**134,710**	**149,661**	**163,012**	**174,931**	**185,575**	**195,078**	**203,563**	**211,139**	**217,902**	**257,719**						
Rate 1	**12%**																	223,940	187,225	1.2		32880	27489
Rate 2	**10%**																	250,204	208,968	1.2		32895	27474
Rate 3	**14%**																	201,857	168,939	1.2		32864	27505
Without SWC practice																							
	Investment costs (Ksh)	-																					
	Materials, tools and others (conti	0	1435	103	103	103	103	103	103	103	103	103	103	103	103	103	103						
	Maintenance costs (Ksh)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						
	Annual cost-maize beans	0	27212	27212	27212	27212	27212	27212	27212	27212	27212	27212	27212	27212	27212	27212	27212						
	Total costs (Ksh)	-	28,647	27,315	27,315	27,315	27,315	27,315	27,315	27,315	27,315	27,315	27,315	27,315	27,315	27,315	27,315						
	Grains (maize/beans) Ksh	0	24806	24310	23824	23347	22880	22423	21974	21535	21104	20682	20268	19863	19466	19076	18695						
	Maize/beans residues (Ksh)	0	5379	5271	5166	5062	4961	4862	4765	4669	4576	4484	4395	4307	4221	4136	4053						
	Napier (Ksh)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				14%		
	Net benefit (NB1)	**-**	**1,538**	**2,266**	**1,675**	**1,095**	**527**	**(30)**	**(576)**	**(1,111)**	**(1,635)**	**(2,148)**	**(2,652)**	**(3,145)**	**(3,628)**	**(4,102)**	**(4,566)**						
Rate 1	**12%**																	(714)	187,225	0.0		-105	27489
Rate 2	**10%**																	(1,904)	208,968	0.0		-250	27474
Rate 3	**14%**																	194	168,939	0.0		32	27505
Scenario 2	*Benefits of SWC practice*																						
	NB_T (NB1-NB2)	-	30,185	30,788	31,380	31,960	32,528	33,085	33,630	34,165	34,689	35,203	35,706	36,199	36,683	37,156	37,621				#NUM!		
	NPV (at 12% rate)	-	26,952	24,544	22,336	20,310	18,456	16,761	15,211	13,799	12,509	11,335	10,265	9,292	8,408	7,602	45,318						
	ANPV	**-**	**26,952**	**51,496**	**73,832**	**94,143**	**112,599**	**129,359**	**144,570**	**158,370**	**170,879**	**182,214**	**192,479**	**201,772**	**210,179**	**217,782**	**263,100**						
Rate 1	**12%**																	224,654	187,225	1.2		32,985	27,489
Rate 2	**10%**																	252,108	208,968	1.2		33,146	27,474
Rate 3	**14%**																	201,664	168,939	1.2		32,833	27,505

NB: Net Benefits NPV: Net Present value ANPV: Accumulative Net Present Value BCR: Benefit cost ratio IRR: Internal Rate of Return PVoA-NB: Net benefit ordinary annuity PVoA-Costs: Cost ordinary Annuity

PART II
COSTS AND BENEFITS OF SOIL AND WATER CONSERVATION PRACTICES: OFF-SITE

November 2011

Authors
E. Njuguna
D.D. Onduru
F.N. Muchena

Series Editors
W.R.S. Critchley
E.M. Mollee

Key Points

- Green Water Credits (GWC) is an investment mechanism that will support rainfed smallholders to strengthen existing, or introduce soil and water conservation measures (*"green water* management" measures as termed under GWC) that will reduce runoff and enhance rainwater infiltration in farmers' fields, and simultaneously reduce soil surface evaporation.

- A study of costs and benefits of off-site impacts of selected soil and water conservation measures were carried out among five large water users along the Tana River. The study focused on KenGen, Delmonte, Kakuzi, Nairobi City Water and Sewerage Company as well as the small-scale irrigators along the Yatta Canal.

- However no data was acquired from the large-scale irrigators, Del Monte Fresh Produce Kenya (no response) or Kakuzi (no available data to share)

- The study has shown that soil and water conservation practices in the Upper Tana catchment lead to benefits that accrue to the institutions, and these make the Green Water Credits programme worth investing. These benefits are:

  - more water for human consumption and sewerage services, because of regulated flows in the reservoirs and the costs of treatment are reduced;
  - more capacity to do irrigation as there is regulated water flow in the river which flows more evenly for longer periods of the year;
  - more capacity to generate electricity as there will be increased flow in the Masinga reservoir .

- While investments are carried out, care should be taken to ensure that the lag periods (the delay) before the benefits accrue are shortened to a minimum and that the gains obtained are sustained over a long period of time, so that the institutions who are in the business of making money can invest in the conservation activities and expect a return within a reasonable time - and sustain such benefits for a long period.

Acronyms and Abbreviations

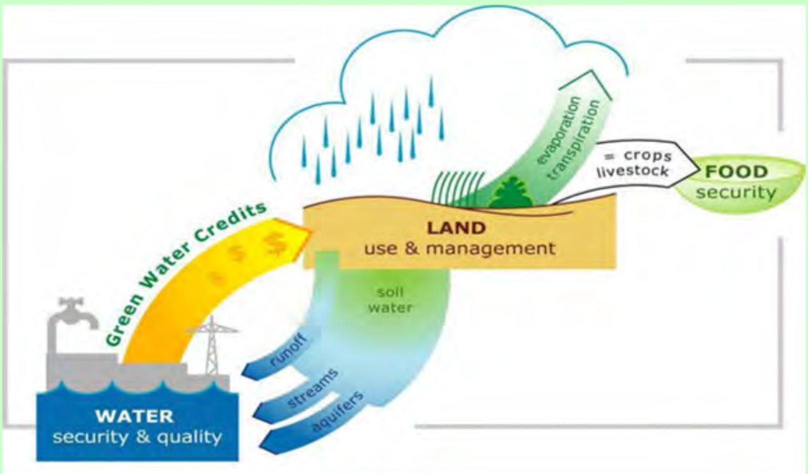
CBA	Cost-Benefit Analysis
CBO	Community Based Organisation
FBO	Faith Based Organisation
GO	Government Organisation
GWC	Green Water Credits
IFAD	International Fund for Agricultural Development
ISRIC	World Soil Information
KenGen	Kenya Electricity Generating Company Ltd.
KFS	Kenya Forest Service
KTDA	Kenya Tea Development Agency
LH	Lower Highlands
LM	Lower Midlands
MKEPP	Mount Kenya East Pilot Project
MoA	Ministry of Agriculture
MoLD	Ministry of Livestock Development
NCWSC	Nairobi City Water and Sewerage Company
NGO	Non-Governmental Organisation
NPV	Net Present Value
NRM	Natural Resource Management
PPA	Power Purchase Agreement
PSCC	Project Specific Cost of Capital
SACCO	Savings and Credits Cooperative Society
SPSS	Statistical Package for Social Scientists
SWC	Soil and water conservation
UM	Upper Midlands
WFP	World Food Programme
WRMA	Water Resources Management Authority
WRUA	Water Resource User Association

Green Water Credits: the concepts

Green water, Blue water, and the GWC mechanism

Green water is moisture held in the soil. Green water flow refers to its return as vapour to the atmosphere through transpiration by plants or from the soil surface through evaporation. *Green water* normally represents the largest component of precipitation, and can only be used *in situ*. It is managed by farmers, foresters, and pasture or rangeland users.

Blue water includes surface runoff, groundwater, stream flow and ponded water that is used elsewhere - for domestic and stock supplies, irrigation, industrial and urban consumption. It also supports aquatic and wetland ecosystems. *Blue water* flow and resources, in quantity and quality, are closely determined by the management practices of upstream land users.



Green water management comprises effective soil and water conservation practices put in place by land users. These practices address sustainable water resource utilisation in a catchment, or a river basin. *Green water* management increases productive transpiration, reduces soil surface evaporation, controls runoff, encourages groundwater recharge and decreases flooding. It links water that falls on rainfed land, and is used there, to the water resources of rivers, lakes and groundwater: *green water* management aims to optimise the partitioning between *green* and *blue water* to generate benefits both for upstream land users and downstream consumers.

Green Water Credits (GWC) is a financial mechanism that supports upstream farmers to invest in improved green water management practices. To achieve this, a GWC fund needs to be created by downstream private and public water-use beneficiaries. Initially, public funds may be required to bridge the gap between investments upstream and the realisation of the benefits downstream.

The concept of green water and blue water was originally proposed by Malin Falkenmark as a tool to help in the understanding of different water flows and resources - and the partitioning between the two (see Falkenmark M 1995 Land-water linkages. FAO Land and Water Bulletin 15-16, FAO, Rome).

1 Introduction

1.1 Background Information

Green Water Credits (GWC) is an investment mechanism that will support rainfed smallholders to strengthen existing, or introduce improved, *green water* management - these are all soil and water conservation measures ("*green water* management" measures as termed under GWC) that will cut runoff rates and enhance rainwater infiltration in farmers' fields, while reducing soil surface evaporation (see "Green Water Credits: the concepts"). The main objective of the GWC concept is that when upstream farmers employ improved *green water* management measures, downstream water users will benefit from improved *blue water* resources – this includes regulated riverflow, reduced sediments in rivers and reservoirs, and recharged groundwater resources. The main downstream water users considered so far under GWC in the Upper Tana basin, Kenya, include: KenGen, Nairobi Water and Sewage Company and other large urban and industrial water users, large irrigating agriculture (e.g. Del Monte and Kakuzi) and smallholder irrigators (e.g. within the Yatta irrigation scheme).

It is envisaged that the implementation of improved land and water management will be realised in two to three demonstration sub-catchments in the Upper Tana, each having an estimated 15,000 to 20,000 smallholder households. The selection of these demonstration sub-catchments will be based upon the Upper Tana Target Areas (UTTA) map (see Figure 1), which delineates hotspots. Implementation will take place under the forthcoming IFAD-funded Tana NRM Project, 2012-2019.

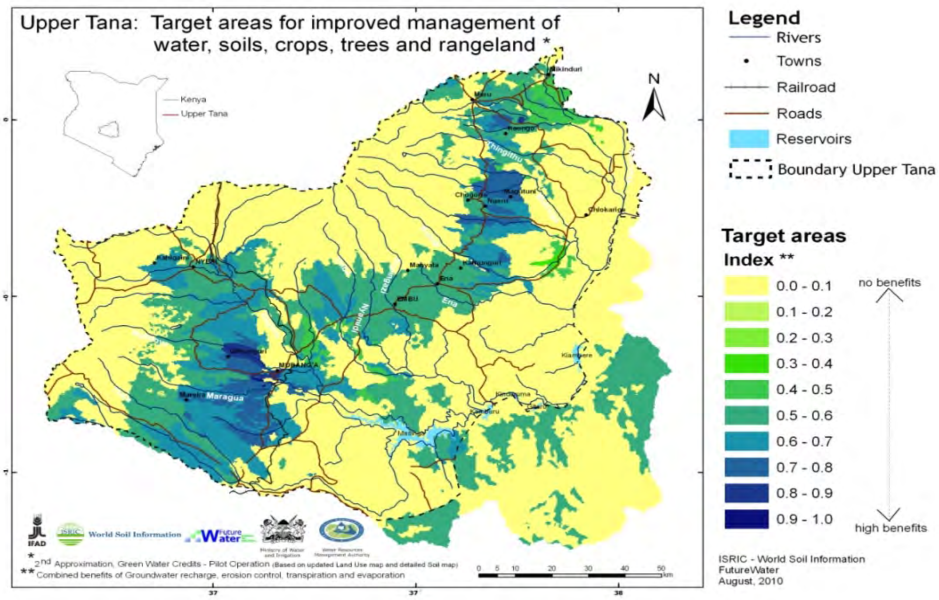


Figure 1
Upper Tana catchment

To achieve the projected improved land and water management, smallholder farmers will require short and long-term investment packages. The short-term packages comprises the regular production inputs that farmers need; namely seeds, fertilizer and other agro-chemicals. The long-term investment package forms the backbone of the GWC concept and consists of the inputs required for improved *green water* management, which consists of labour, tools, mulch materials, cover crops, grasses for vegetative barriers and tree seedling. A portion of these long-term investments will be covered by GWC Investment Fund and other Environmental Services grants, most probably in the form of soft loans or grants in the form of vouchers.

The investment package should follow the principle of a "Commercial Sustainable Investment Package" as advocated by Equity Bank. Innovative in the CSIP is the long-term investment part. The Commercial Sustainable Investment Package works well for regular farmers' loans that address seasonal inputs for recognised commodities such as tea, coffee, grains, livestock, etc. However, the challenge is to further develop the CSIP for a combined package that includes the long-term investments inputs required for some soil and water conservation practices. In particular these investments, once introduced to many farmers, will lead to private and public benefits in terms of: (i) on-farm productivity, (ii) groundwater recharge, reduced flooding and reduced siltation of surface water, (iii) sustainably protected natural resource base of soil and water; and (iv) resilience to climate change.

ETC East Africa was commissioned by ISRIC to carry out cost-benefit analyses for the development of the Commercial Sustainable Investment Package and the GWC investment fund. The cost-benefit analysis was divided into two parts; one that focused on the on-farm costs (see part I of this report) and benefits and one that focused on the off-site costs and benefits. This paper reports on the second part of the cost-benefits analysis that focuses on the institutions offsite.

1.2 The study respondents

There are major waters users downstream of the Tana basin who are potential buyers of Green Water Credits and who were the respondents of this analysis of off-site costs and benefits of soil and water conservation practices. They include:

– The Kenya Electricity Generating Company Ltd (KenGen)
– The Nairobi City Water and Sewerage Company
– Yatta Irrigation Scheme smallholders

Kenya Electricity Generating (KenGen) Company Limited

Hydropower is strategically important to Kenya. It provides 50-80% of the national electricity depending on rainfall. Installed capacity is 650 MW/year, technically exploitable capability may be 9 TWh/year (UNESCO 2006). Eighty percent of hydropower is generated from five dams on the Tana river. In addition, there are two smaller hydropower plants upstream of Masinga: The Tana power station (14.4 MW) and the Wanji power station (7.4 MW).

Table 1
Dams in the Tana river cascade with their installed capacities and the dates they were commissioned

	Name of Dam	Installed capacity (MW)	Date commissioned
1	Kindaruma	44	1968
2	Kamburu	94.2	1974
3	Gitaru	225	1978, 1999
4	Kiambere	144	1988
5	Masinga	40	1981

Source: Hoff *et al.* 2007

The Kenyan national population is about 35 million (GoK 2009) with an annual growth rate of 2.5%. In 2004, the Kenyan electrification rate was estimated at 7.9% as 27.7 million people did not have access to electricity (UN Millennium Project 2004). Both electricity generation and consumption rose by 6.8% in 2005 (GoK 2006). The Kenya Power and Lighting Company (the precursor of KenGen) estimated that the demand for power would be 2397 MW by the year 2025. There are difficulties in meeting this rise in demand for electricity. Extreme weather events are a huge risk to the hydropower industry. During the 1999-2000 drought, hydropower generation fell by 41% (from 3000 to 1800 GWH); monthly losses to the hydropower industry were estimated at US$ 68 million, and lost industrial production of US$ 1.4 billion. Some foreign investors relocated to neighbouring countries with more secure power supplies (Mogaka *et al.* 2006). Any significant rainfall event with particularly high intensity rainfall brings floods, soil erosion and siltation that affects hydropower infrastructure through the loss of reservoir storage capacity and damage to turbines that require frequent repair and replacement.

Upstream land management practices that would result in better regulation of riverflow would bring direct financial benefits for KenGen electricity generation efforts. KenGen was considered a potential buyer of Green Water Credits in the Tana basin.

Tana river irrigators

Kenya's agricultural sector is the mainstay of the national economy; it provides the basis for development of the other sectors. Its direct contribution to the GDP is 26% while a further 27% contribution is indirect through linkages with agro-based and associated industries. Overall, the agricultural sector employs over 80% of the total labour force, generates 60% of foreign exchange earnings and provides 75% of industrial raw materials and 57% of the national income.

The agricultural sector accounts for a large proportion of water use in Kenya. Irrigators in the Tana basin include large commercial farmers (Del Monte and Kakuzi) and public schemes (Mwea, Bura, Hola) as well as community based smallholder schemes (Yatta Canal). Demand for irrigation water greatly outstrips supply. Currently, there are 68,700 hectares under irrigation but there are more than 205,000 ha of potentially irrigable land. Inconsistent supply and lack of water limits output from the current 68,700 hectares under irrigation.

Upstream land management practices that would result in better regulation of river flow, thus availing water for irrigation for longer periods, would bring direct benefits to the irrigators and the country as more land is put under irrigation and production in the already irrigated land is enhanced. The large-scale and small-scale irrigators are therefore potential buyers of Green Water Credits in the Tana basin. The Yatta Water and

Sewerage Company, which abstracts water from the Yatta canal for supply to the Matuu domestic and institutional consumers, were also interviewed during the study. Kakuzi and Del Monte were chosen to represent the large-scale irrigators, while the Yatta canal farmers were sampled to represent the small-scale irrigators. Due to difficulties in obtaining data from Kakuzi and Del Monte, they are not included in this report.

The Nairobi City Water and Sewerage Company

Nairobi, the capital city of Kenya, gets 70-80% of its water from the Ndakaini reservoir in the Upper Tana while the balance comes from the Sasumua and Ruiru reservoirs also in the Tana basin. A small proportion of the water is obtained from wells and springs near Nairobi and springs in the Kikuyu area. Supply of water in the city is the responsibility of the Nairobi City Water and Sewerage Company (NCWSC), previously called the City Council Water Department but now instituted as a subsidiary company (GoK 2006).

Municipal water demand from the Nairobi City Water and Sewerage Company is increasing strongly with the population in Nairobi growing at 6% annually and industrial water demand projected to grow from 220,000 to more than 280,000m^3/day by 2010 (UN Water 2006). Currently, the NCWSC is unable to meet daily water demands. In the June-September 2006 dry season, demand for water was 570,000 m^3/day but only some 456,000 m^3/day was abstracted (384,000m^3/day from Ndakaini reservoir), a shortfall of 20%. NWC anticipates a 3-5% annual increase in demand, so unmet demand continues to be a serious issue.

Siltation of reservoirs is a significant cost to the NWC. US$ 50,000 was spent in the period between 2003 and 2006 to dig silt from the Sasumua reservoir. Water purification is also a significant cost due to contamination of the water supply from agricultural practices.

Upstream land management practices that result in better regulation of riverflow and better quality of water would bring direct benefits to the NCWSC and the water consumers in Nairobi and Thika Municipalities. Sustainable management of water resources and increased flows to meet unmet water demand would interest the NCWSC to be a stakeholder in the Green Water Credits.

1.3 Objective of the Study

The objectives of the off-site cost benefit study, as defined in the TOR's of the consultancy were to:
- Conduct an off-site economic evaluation of hydrological benefits of *green water* measures as identified in various GWC reports in consultation with the main water users (Kakuzi, Del Monte, KenGen, Nairobi water company and Yatta smallholder irrigators)
- Estimate the avoidable costs that *green water* management could save GoK in disastrously dry and wet years (those with El Nino and El Nina effects) in terms of flooding intensity, productivity losses, food security etc.

2 Approach and methodology

2.1. General approach in data collection

The study was conducted in five steps that were continuous but discrete in terms of activities undertaken in order to generate the expected outputs. These steps included (1) discussions with clients, literature review and development of data collection tools; (2) developing the approach and methodology for the study (3) field data collection; (4) data entry and analysis; and (5) report preparation.

Contact persons from each of the sampled organisations were identified through the help of key informants in the project. Phone calls were made and emails sent to the organisational contacts in order to book appointments during which the research team explained the study objectives. These initial interviews were successfully done with all the institutions. The data tools that had been pre-prepared were presented and information sought on whether they were appropriate to capture the relevant data specific to the company. Where the contacts felt that not all issues were captured, the data collection tool was reviewed and revised. This data collection tool was left with the representatives from the companies for an agreed period of time in order to collate the data that was required. At an agreed date, the research team went back to collect the data, which was then analysed in Excel for presentation. Data was obtained from KenGen, from the Nairobi City Water and Sewerage Company and the Yatta small-scale irrigators as well as the Yatta Water and Sewerage company. Data was not available from Del Monte and Kakuzi. Kakuzi indicated that they were re-organising their farming business and they had not used water for irrigation, they were currently not making any investments in dam maintenance and they therefore did not have data to share with the team. Del Monte did not respond despite several reminders

2.2 Cost Benefit Analysis Methodology

Cost-benefit analysis (CBA) is a method of economic evaluation for projects, programmes or policies that measure benefits and costs, as far as is possible, in monetary terms (Australian Government 2007). It is concerned with identifying and measuring, where practical, and then discounting future costs and benefits to present values to enable the calculations of the net economic worth of project options. CBA is an approach to public sector investment appraisal that can provide useful information to decision makers about the most economically viable option out of a range of alternatives. It differs from a financial appraisal or evaluation in that it considers all gains (benefits) and losses (costs) regardless of to whom they accrue. Financial evaluation is concerned with how to fund a project over its lifespan and measures the adequacy of revenue cash flows to cover the costs of the project. CBA considers the costs and benefits to the wider community; whereas financial evaluation looks at the financial costs and benefits to a particular entity. The purpose of a CBA in this situation is to help establish if Green Water Credits operations are economically justifiable and whether they provide net economic benefits to the buyers and suppliers of the Green Water Credits. CBA involves an incremental assessment; that is evaluating a project option against a base; it considers costs and benefits that accrue which could be caused by potential changes to the base case or “business-as-usual” scenario.

The “base case”

Cost-benefit analysis can’t be conducted without the base case. The base case provides the bench mark against which the proposed project can be measured. The base case is a “business-as-usual” scenario. The “business-as-usual” scenario requires a description of what is likely to occur in the absence of the Green Water Credits operations[9]. The “business-as-usual” situation includes changes to the existing situation that are, for all practical purposes, unavoidable.

The respondents from the institutions were requested to consider three different scenarios in providing data for the different variables in the data collection tool where it was practical to do so: a normal year, a drought year and a flooding year.

Costs and benefits

Costs and benefits that can be directly expressed in economic (monetary terms) are referred to as quantitative. Costs or benefits that can’t be quantified in economic terms are referred to as qualitative benefits/costs. Only those quantified costs and benefits directly attributable to the use of, and conservation of, water were considered for each responding institution. Quantified costs and benefits were identified and described. These were assumed to be the costs and benefits that are likely to change due to the proposed Green Water Credits intervention.

Present values and discounting

The costs and benefits were considered for a period of 15 years, since the *green water* intervention is a long-term strategy. Since responding institutions are not indifferent with respect to the timing of costs and benefits, it was necessary to calculate the present values of all costs and benefits. Discounting is the principle applied to express future costs and benefits in their present values (PV). Discounting was performed based on the assumptions that immediate incomes or benefits are preferred to future income or benefits (“social time preference”) and capital investments have an opportunity cost; it could earn a rate or return in other sectors of the economy if it were not used for the Green Water Credits project (opportunity cost of capital).

The PV is calculated using the method of compared interest and the rate that converts future values into PV is the “discount rate”. The discount rate is used to convert costs and benefits that occur in different time periods to PV so that they can be compared. The PV of costs and benefits can be expressed as follows

$$PV = \sum_{n=0}^{N} \frac{C_n}{(1+r)^n} \qquad \text{...Eqn 1}$$

Where

c_n = the costs in year n expressed in constant dollars
r = the real discount rate
n = the evaluation period in years.

In the preparation of a CBA, this process is known as the discounted cash flow method.

Selecting a discount rate

The generally preferred approach is to use a real discount rate; that is to exclude any inflationary component of market rates. Inflation must be treated consistently across both the applied discount rate and the costs and benefits components of the evaluation. If costs and benefits are measured in nominal or current dollars, then a nominal discount rate is used.

[9] Note: the base case is not costless

A common rate used for discounting purposes is the government borrowing rate (returns on government bonds). Discounting factors of 10%, 12% and 14% were used for scenario analysis since the Kenyan government bond is currently pegged at 12.5%. Alternative measures of opportunity costs include the social opportunity cost of capital (SOC), which is determined by the equivalent return that may be able to be received by another project (whether in public or private sector). This application is problematic in a practical sense due to the limitations associated with the project choice. SOC is generally higher than the government borrowing rate. Project specific cost of capital (PSCC) is a market based assessment of the projects volatility. In some countries, the long-term average real economic growth rate can be used with an allowance for major risks and time preferences. The rate of return on debt and equity for comparable private sector projects have also been used as discount rates as public sector projects would be competing with other activities for debt and equity capital.

Price/Base year

The price year in an economic evaluation is the year in which the value of all costs and benefits are expressed; the dollar units represent the same purchasing power. The base year is the year to which costs and benefits are discounted to arrive at a PV, and it affects the magnitude of the reported results, with an earlier year resulting in lower magnitude of the reported results. It is preferable to discount to the base year in which the decision to proceed is made so that the PV mean just that. The base year could also be the year in which the evaluation is conducted and it should be common to all alternatives being considered. The base year was considered to be the year 2011.

The evaluation period and economic life

The PV of costs and benefits are measured over a set evaluation period. In comparing projects, it is important to evaluate options over the same time period. The economic life of a project is the period of time over which the benefits to be gained from the project may reasonably be expected to accrue. Since the conservation efforts may take time to deliver benefits, 15 years were considered to be prudent for analysis.

Inflation and interest rates

The effects of inflation should not distort the costs and benefits streams. Inflation causes the costs and benefits that occur later in the evaluation period to appear higher than they should. This causes a bias towards projects with later benefits. Inflation does not increase the real value of costs and benefits; it only increases their monetary value. Real or constant prices were therefore used in the cost-benefit analysis.

Decision criteria for the off-site cost benefit analysis

There are a number of alternative criteria for the assessment of the economic value (net economic worth to society) of projects. The criteria used in this study are the net present value and the benefit-cost ratios.

1. Net present value – is the sum of the discounted project benefits less discounted project costs. It can be expressed as;

$$NPV = \sum_{n=0}^{N} \frac{Bn - Cn}{(1+r)^n} \quad \text{………………………………………………..Eqn 2}$$

Where:

B_n = benefits in year n expressed in constant dollars

C_n = costs in year n expressed in constant dollars

r = real discount rates

n = evaluation period in year.

Using NPV as a decision rule, a project is potentially worthwhile (or viable) if the NPV is greater than zero. When comparing mutually exclusive alternatives, the alternative that yields the highest NPV would be chosen. Issues that may arise with use of the NPV relate to:

– The impact of budget constraints
– Complementarities among projects
– The interaction of budget constraints and project timing choice
– Comparison of projects with different lengths of life.

2. Benefit-cost ratio (BCR) – is the ratio of the PV of benefits to the PV of costs. The BCR can be expressed as follows:

$$BCR = \frac{pv_{benefits}}{pv_{\cos ts}} \text{ ,..Eqn 3}$$

Where

$$PV_{benefits} = \sum_{n=0}^{N} \frac{B_n}{(1+r)^n}$$

And

$$PV_{\cos ts} = \sum_{n=0}^{N} \frac{B_n}{(1+r)^n}$$

A project is potentially worthwhile if the BCR is greater than 1. This implies that the PV of benefits exceeds the PV of costs.

3 Findings

This chapter presents the findings of the study. The findings are presented in three sub-sections as follows:

- Section 3.1: Yatta smallholder irrigators and Yatta WASCO
- Section 3.2: Nairobi Water Company
- Section 3.3: Kenya Electricity Generating Company Ltd.

3.1 Yatta smallholder irrigators and Yatta water and sewerage company

Yatta District is in the Eastern Province of Kenya; it was carved out of Machakos district in March 2007. It borders Mbeere District to the north, Kitui District to the east, Thika East and Thika West Districts to the west, Maragwa District to the south-west and Kangundo and Mwala Districts to the south. The district covers a total area of 1057 $km^{2.}$ The district is divided into three administrative divisions which include Yatta, Ikombe and Katangi.

Yatta District has three permanent rivers running through it, namely the Athi river, the Tana river and the Thika river. These rivers provide most of the water used for irrigation in the district. The Yatta furrow provides water for irrigation for over 30 group based irrigation schemes and two institutional irrigations including the National Youth Service and the Kenya Wine Agencies Limited. Irrigation potential in Yatta district is estimated at 4,448 hectares but only 1,028 hectares have been exploited, supporting approximately 993 households. The irrigation schemes are gravity-fed and are situated along the Yatta canal e.g. Kithendu A, Kithendu B, Muthesya, Mamba A and B among others. The main crops grown along the irrigated land include Asian vegetables, *kalera* (*Momordica charantia* or "bitter gourd" in English), green maize, *sukuma wiki* (*Brassica* sp. or "kale" in English) and fruit trees. The main irrigation application methods are basin and furrow methods.

The Yatta Water and Sewerage Company (Yatta-WASCO) draws water from the Yatta furrow, treats it at a plant in Matuu town and distributes it to domestic and institutional consumers in the town and the surrounding urban centres. Yatta WASCO regulates the flow of water to the small-scale irrigators along the Yatta furrow and charges them for water used (water charges for irrigation water levied on membership but not pegged on the amount of water abstracted for irrigation).

Water flow in the Yatta furrow/canal was the basis of analysis of benefits that may accrue to the small-scale irrigators in Yatta (Fig 2) with the implementation of soil and water conservation in the Tana catchment through the Green Water Credits project. The Yatta furrow is 60 km long from the point of water intake to the last household which can draw water for irrigation. During a high rainfall year or during one with a normal rainy season, the Yatta furrow has water flowing through the 60 km of its length: however, during a drought year, only about 26-28 km of the canal has water flowing. Thus not all the farmers can access water throughout the year for irrigation purposes. Some of the domestic users also have to do without water in some periods of the year. In a normal year, there are fluctuations from month to month with regard to how much water flows in the furrow, with an average of approximately 46 km.

Water availability and use efficiency would be improved along the Yatta canal if the canal was lined to reduce the water loss through seepage, re-shaping the canal to reach more farm households, constructing concrete off-take structures along the canal as well as rehabilitating some of the open water systems to become closed systems to improve water use efficiency. A further improvement would be the adoption of *green water* management technologies in the catchments areas leading to more water availability for more months in any year.

Depending on management, crop, rainfall and local soil and terrain, *green water* management will:

– Reduce sediment input to the Masinga reservoir by 22-72% (0.3-2.5 million tonnes per year)
– Increase groundwater recharge from cropland by 4-57% (16-160 mm per year) representing a potential annual gain of accessible water of 160-1600 m^3 per hectare
– Cut damaging runoff by 22-66%
– Reduce unproductive evaporation of water from the soil surface by up to 15% (50 mm per year), representing a water gain of 500 MCM/ha/year.

We could assume that the increase in groundwater recharge of 16-160 mm per year, leading to an annual gain of accessible water to 160-1600 m^3 per ha attributed to the GWC activities, would lead to higher flows into the water bodies that feed into the Yatta canal extending water availability in the furrow to the 60 km mark and for longer. This can be assumed to impact on the number of months when the 60 km canal has enough water to meet the needs of the domestic consumers and irrigators and hence improve:

– the total number of hectares under irrigation in the area;
– the number of domestic consumers and irrigators that would be served by Yatta WASCO;
– the savings Yatta WASCO would make from avoided costs of carrying water in bowers for emergency water supply to institutions (e.g. the hospital) and other consumers; and
– the savings Yatta WASCO would make from de-silting activities of the Yatta canal.

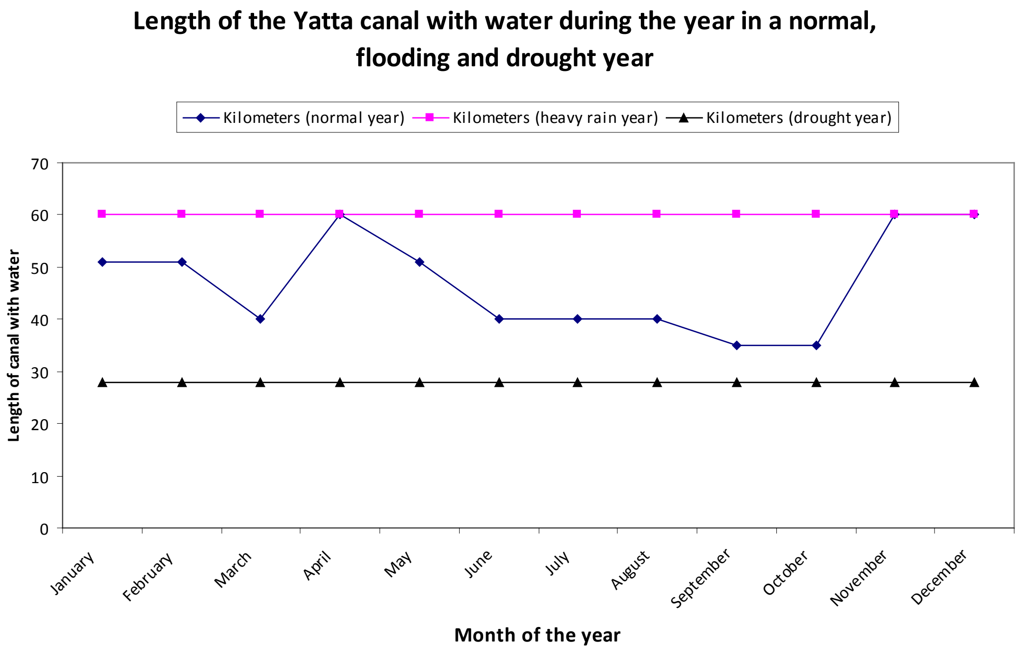


Figure 2
The length of Yatta canal with flowing water during a normal, flooding and drought year (source: Yatta WASCO office, Matuu)

Assumptions for the costs and benefits analysis for the Yatta WASCO supply for consumption and smallholder irrigation:

1. The length of the Yatta canal is 60 km. Although the flow rate for the canal is 2.2 m^3/s, only 1.1 m^3/s is attained currently[10]. Currently, only 28 km of the canal has water flowing during a drought periods. In some instances after the rains, water in the canal can flow to a length of 46 km. *Green water* management measures are assumed to increase the water flow to a distance of 46-60 km for most parts of the year. This improvement can be attributed to increase in groundwater recharge and also the reduction in siltation of the canal.
2. There are 1000 potential small-scale irrigators along the canal. Due to the limitations of the water flow, only 600 small-scale irrigators are currently able to abstract water from the canal for irrigation over the year. We can assume that with the *green water* management measures, there will be potential to serve 150 more irrigators along the canal.
3. There are 317 consumers who are currently being served by the Yatta WASCO with piped water after treatment from the canal. There are 400 other water users who can be supplied with piped water and we assume that with the GWC and better waterflows in the canal, these consumers will be supplied with piped water.
4. Although the Yatta small-scale irrigators grow different crops under irrigation, we assume that the land brought under irrigation as a result of improved waterflows due to the GWC activities will be put under *sukuma wiki*. *Sukuma wiki* is a popular vegetable with market demand in the rural and urban areas of Kenya, throughout the year. The gross margins for *sukuma wiki* are shown in Annex 2 of this report.
5. If the GWC operations lead to abstraction of higher amounts of water from the Yatta canal, the levies payable to the Water Services Board and the Water Resources Management Authority will increase for the Yatta WASCO.

Table 2

The costs and benefits accruing to the Yatta community (the water and sewerage company as well as the small-scale irrigators) if the 60 km canal has sufficient water to meet the needs of the community for most of the year

	Base Year
A: Total revenue gains to Yatta community	**36,846,424.69**
Reduction in costs by Yatta WASCO of emergency water supply to institutions during drought	1,323,620.00
Revenue to Yatta WASCO from higher numbers of irrigators	750,000.00
Revenue to Yatta WASCO from higher numbers of water users provided with piped water	160,000.00
Higher benefits to Yatta small-scale irrigators from farms under irrigation (based on gross margins for *sukuma wiki*; could be higher if high value vegetables are irrigated and marketed)	34,612,804.69
B: Total costs increase for the Yatta community	**11,854,993.00**
Change in costs of water treatment (assumed to increase to level of flooding)	1,471,010.00
Change in levies to WRMA	72,096.00
Change in levies to Tana and Athi/WESREB	311,887.00
Change in costs of desilting the canal	10,000,000.00
Net benefits (a-b)	**24,991,432**
Benefit-cost ratio	**3.11**

[10] pers. comm., Irrigation officer, May 2011

Considering the costs and benefits accruing to the Yatta community for the next 15 years (See Annex 3 for annual cost and benefits discounted at three different rates), we get a net present value of between KSh 153 and 190 million.

Table 3

Net present value of benefits accruing to the Yatta community for a period of 15 years (the water and sewerage company as well as the small scale irrigators) if the 60 km canal has sufficient water

	NPV in KSh	NPV in US$ (KSh 100 to US$)
Net benefits discounted at 10%	190,084,829	1,900,848
Net benefits discounted at 12%	170,214,142	1,702,141
Net benefits discounted at 14%	153,504,871	1,535,049

3.2 The Nairobi City Water and Sewerage Company

According to a report done by Samwel Kumba for the Daily Nation on the 10th April 2010, Nairobi's first water source was commissioned in 1899. It was based on the Nairobi river in the Athi river basin. The project resulted in inadequate and low quality quantities. The Kikuyu springs were then developed between 1900 and 1906 to produce approximately 4.5 million litres per day. In 1938, the first phase on the Ruiru river was developed encompassing an intake weir and a pipeline. By 1949, there were three pipelines serving the city of Nairobi from the Ruiru river.

The next development in Nairobi's water supply was the Sasumua dam that was initially fed by waters from the Sasumua river and supplemented by a diversion from the headwaters of the Chania river. The Kiburu river waters were later diverted into the dam.

As of 1986, the Kikuyu springs produced 4 million litres of water a day, Ruiru dam produced 21 million litres, Sasumua produced 46 million litres while the Chania river at the Mewangu intake produced a total of 192 million litres of water for Nairobi. This supply was not enough, since the human population was increasing at a high rate. The water and sewerage systems in the city were strained as unplanned settlements of the suburbs and the expansion of dwellings in the informal settlements increased. In 1985 a project to develop the Thika (Ndakaini) Dam was initiated to curb the water shortage in the city and was commissioned in 1996.

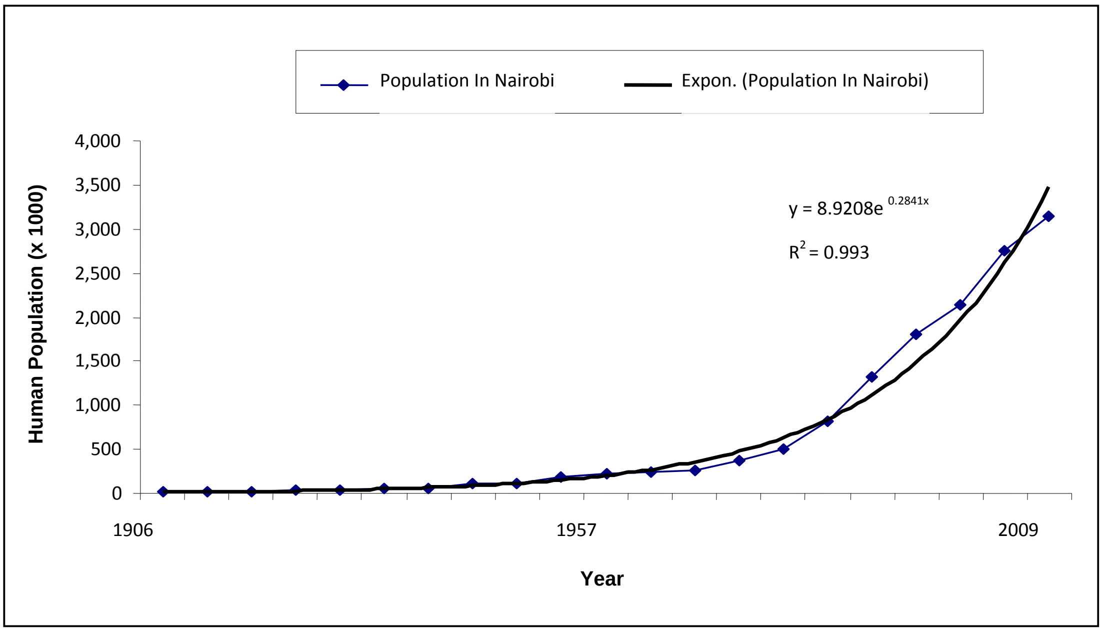


Figure 3
The population of Nairobi City from 1906 to 2009

Figure 3 shows that the human population in Nairobi has been growing exponentially since the 1900s, with the rise in population increasing at higher rates in recent years. In 1906, the emerging capital city had a population of approximately 8,920 persons which grew to over half a million by 1969. It took a much shorter time to hit the one million mark which happened by the late 1980s: since then the increase in population in the city has been even faster and it currently stands at over 3 million persons. It is predicted that with a growth rate of over 3.5%, the city population will be just below 4 million by 2015 and about 5 million by 2025. This growth in human population requires a commensurate growth in water supplies for industrial, domestic use as well as sewerage services. Currently, Ndakaini Dam supplies 80% of Nairobi's water while Sasumua supplies 15%; Ruiru Dam and Kikuyu Springs combined provide 5% of the current city consumption.

Although the Ndakaini Dam supplies 80% of the water to the City of Nairobi currently, the volumes of water in the dam are not always consistent. In 2001, the lowest volumes of water (less than 50% of the reservoir capacity) were recorded due to drought effects; similarly in the year 2009 (see figure 4). With a population that is growing exponentially and a water supply that most of the time is constant or reducing, the challenge of water deficits is serious for the city of Nairobi in both the short and long run. There are plans to expand the Nairobi Metropolitan area by developing six satellite cities around Nairobi in order to decongest it. This will ultimately increase the demand for water six-fold as the populations in those satellite cities join the city demand for domestic, industrial and sewerage water services. Analysing the trends in water demand and supply capacities for Nairobi indicates that there is a growing deficit which will require new investments in water supply and/or improved management of the catchments to ensure more regulated flows in water bodies.

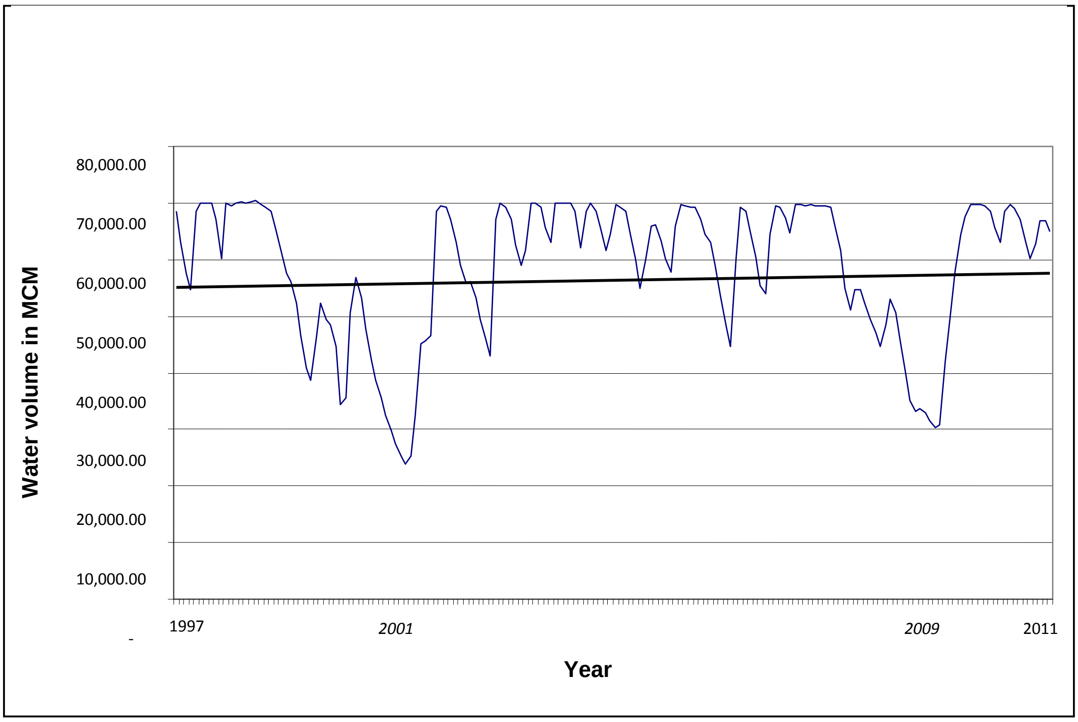


Figure 4
Water volume in million cubic meters at Ndakaini Dam from 1997 to 2001

Potential impact of the conservation effects on the annual costs of the NCWSC.

Data was obtained from the Ndakaini Dam and the NCWSC offices regarding the costs the company incurs annually in supplying water to the city of Nairobi. Costs at Ndakaini Dam office are used here for the cost-benefits analysis. The costs components include chemicals for water treatment, management and administrative costs as well as labour and staff development. Analysis of the costs for the year 2009 and 2010 shows that currently, 13.31% of the Ndakaini Dam's annual budget goes into buying chemicals for water treatment.

The Green Water Credits catchment conservation efforts would focus on reducing the costs of water treatment as well as regulating the water flow into the dams' reservoir especially the Thika (Ndakaini) Dam. Assumptions are made to consider two scenarios: where the percentage of water treatment costs would fall to 10% or 8% (all other costs remaining constant) as water with less sedimentation would get into the water system due to conservation activities.

Results show that under the current costs scenarios, it costs KSh 433.4 to supply one resident of Nairobi with water for a year (based on water costs), and it costs KSh 57.67 to treat water for one Nairobi resident for one year (Table 3). If the *green water* management activities would result in reduction of erosion and sedimentation of water entering the water supply system hence saving the NCWSC money of de-silting the dams, the intakes and weirs leading to a 3% decrease in the percentage costs of chemicals, then the costs of supplying water to a resident in Nairobi would drop to KSh 419.09 while the costs of treatment of water for each Nairobi resident falls to KSh 43.3. If the percentage costs of water treatment drops to 8% of the total company costs, the costs of supplying water to a resident in Nairobi would reduce to KSh 410.42 while the costs of treatment of water for each Nairobi resident drops to KSh 34.67.

Table 4

Analysis of costs and benefits associated with green water management activities on Nairobi City Water and Sewerage Company

	Year 2009	Year 2010	Average annual budget	Annual costs with GWC reducing costs of treatment to 10%	Annual costs with GWC reducing costs of treatment to 8%
Annual budget costs for Ndakaini Dam (KSh)	1,428,535,299	1,291,905,174	1,360,220,236	1,315,254,026	1,288,049,621
Costs of water treatment chemicals	158,196,028	203,780,440	180,988,234	136,022,023	108,817,618
Costs of water and conservancy	5,658,450	266,333	2,962,391	2,962,391	2,962,391
Costs of licensing, lease and levy	520,571,124	526,227,562	523,399,343	523,399,343	523,399,343
Percentage of water treatment costs to total costs			13.31	10.34	8.45
Nairobi population by the census of 2009			3,138,369*	3,138,369	3,138,369
Savings due to GWC conservation efforts				**44,966,210.35**	**72,170,615.50**
			KSh per resident without GWC	**KSh per resident with GWC reducing costs of treatment to 10%**	**KSh per resident with GWC reducing costs of treatment to 8%**
Cost of providing water for one resident in the City of Nairobi			433.42	419.09	410.42
Cost of treating water for one resident in Nairobi			57.67	43.34	34.67

* Results of the Kenya National Population Census in 2009 (GoK 2010)

The potential savings due to the company per year would range from KSh 44 – 72 million per year due to reduction in budget allocation to water treatment chemicals. This would translate to potential Net Present Benefits of KSh 359 to 445 million if discounted between 10% and 14% over a period of 15 years.

If the Nairobi City Water and Sewerage Company could invest between KSh 22-36 million a year in conservation activities among the smallholder farmers, then they can realise a cost- benefit ratio greater than 1 to ensure a positive return on investment.

Table 5

Net present value of benefits accruing to the Nairobi City Water and Sewerage Company for a period of 15 years if the conservation activities lead to reduction of chemical cost budget by 3-5%

	NPV in KSh	NPV in US$ (KSh 100 = US$ 1.0)
Net benefits discounted at 10%	445,471,349	4,454,713.49
Net benefits discounted at 12%	398,903,604	3,989,036.04
Net benefits discounted at 14%	359,744,763	3,597,447.63

NB: The benefits that the company may accrue from increased waterflows and therefore better capacities in supplying water were not computed in this analysis

3.3 Kenya Electricity Generating Company.

The Kenya Electricity Generating Company (KenGen) Limited is the leading electric power generating company in Kenya, producing about 80% of electricity consumed in Kenya. The company utilises various sources to generate electricity ranging from hydro, geothermal, thermal and wind. Hydro is the leading source, with an installed capacity of 766.88 MV, which is 64.9% of the companies installed capacity. KenGen sells power in bulk to Kenya Power (formerly the Kenya Power and Lighting Company) which transmits, distributes and retails electric power to various categories of consumers throughout the country. KenGen is currently operating in a liberalised market and is in direct competition with four independent power producers which generate about 20% of the countries electric power.

Power Purchase Agreements (PPAs) between KenGen and KPLC determine how KenGen supplies electrical energy from power stations to KPLC. In the PPAs, KPLC is required to purchase and pay for the electrical energy delivered to KPLC as well as the available capacity in respect of the power plants. The final payments for capacity and energy are computed as per the various formulae provided in the individual PPAs. In the event that KenGen is not able to have a pre-agreed capacity levels in line with the stipulation the PPAs, an adjustment to cater for the shortfall is levied by KPLC in line with the set formulae. The energy regime means that KPLC pays for the energy supplied from the power stations.

KenGen has a corporate environmental policy statement which commits the company to long-term environmentally sustainable development that is consistent with the national and international standards in the generation of safe and reliable electric energy. However, the company is not directly involved in long term conservation projects (except tree planting) at the smallholder level.

KenGen uses water resources in the Tana basin for electric power generation; however, the Masinga and Kiambere Dams are owned by the Tana and Athi Rivers Development Authority (TARDA). Siltation trends in the dam are supposed to be monitored by TARDA. Conservation interventions in the catchment's areas are the mandate of TARDA. KenGen is only involved in the operational interventions if something arises on the Masinga and Kiambere Dams. KenGen pays an annual conservation levy to TARDA for conservation efforts (and also Kerio Valley Development Authority for the Turkwell Dam)

KenGen is supposed to pay a levy to the Water Resources Management Authority (WRMA) at a rate of five cents for every KWH generated for using the water resources. The tariff structure for KenGen is regulated by the Energy Regulatory Council and it is based on costs. The WRMA levies had not been factored-in the tariff structure for KenGen and the company is therefore not yet able to remit any levies to WRMA as yet. If the WRMA tariffs are factored into the cost structure for power, the cost of electric power in Kenya is bound to rise affecting the economy in general. This is against a background of consistent rising of fuel costs and a weakening Kenyan currency. Any other initiative requiring KenGen to make a financial contribution should plan with an understanding that the KenGen tariffs are regulated and based on costs.

The main impacts of erosion and siltation in the Upper Tana on KenGen are increased sedimentation in the reservoirs, especially Masinga Dam, which leads to loss of reservoir capacity and reduction in dam service life. However, discussion with a hydrology officer at KenGen indicated that the machinery for the turbines is manufactured with erosion in mind. Reducing erosion might not provide the highest benefit to KenGen.

The irregular flow of water into Masinga Dam during drought periods is the biggest challenge, sometimes occasioning a need to generate emergency power using diesel and also a need to ration electricity distribution to the consumers. This in effect leads to loss in productivity, not only for KenGen but also for the economy as a whole. Table 5 summarises the main effects of erosion on KenGen's operations.

Table 6
Impacts of soil erosion and siltation on KenGen operations

	Current scenario
Main impacts of soil erosion and runoff	
Rate of sedimentation (planned)	0.6 - 0.9 tonnes/yr (design value)
Rate of sedimentation (actual)	13.4% (estimated)
Loss of reservoir's capacity	less than 10% (estimated)
Reduction in dam service life	7.5 years (estimated)
Unplanned increase in sedimentation of dead storage	13.4% (estimated)
Planned increase in sedimentation of dead storage	0.6 - 0.9 tonnes/yr (design value)
Reduction on power generated and distributed	100 MW per annum
Higher costs of electricity	16.22 Usc/KW/Month
Cost of emergency electricity generation	16.22 Usc/KW/Month
Unmet domestic and industrial demand for electricity	250 MW (from load shedding data)
Change of productivity	Loss of 690 GWh/yr
Capital costs	15 billion KSh (Dam wall raising cost)
Recurrent costs	10 million KSh (soil conservation efforts)
Avoidable capital costs	15 billion KSh (Dam wall raising cost)
Avoidable recurrent costs	10 million KSh (soil conservation efforts)
User comfort and convenience	Reduced availability by 12%
Quality of service	Regular power rationing inconveniencing consumers

Currently, the actual rate of sedimentation in the Masinga Dam is 13.4% which is estimated to lead to a shortening of service life by 7.5 years (P. Kollikho, pers comm). The loss in productivity is estimated to be equivalent to 690 GWh/yr; besides the occasional power rationing to industrial and domestic consumers who are greatly inconvenienced. This leads to losses under four categories:

- Losses to KenGen (electricity not generated, emergency power generation costs, loss of business)
- Losses to the industrial and commercial consumers (sub-optimal operations, losses in emergency power generation)
- Losses to the domestic consumers (refrigerated food losses and electronic equipment)
- Loss of international investments as the investors choose to go to other competitive destinations.

Adoption of *green water* management technologies would lead to improved flows into the Masinga reservoir. Future Water modelled the amounts of water that would flow into the dam, for a period since 2000 to 2009, if smallholders adopted bench terracing. The research team is consulting with KenGen to put value on how much more electricity would be generated throughout the 5-Dam cascade from this higher flows into the Masinga Dam reservoir. With this value it will then be possible to estimate the gains to the consumers and business Kenya.

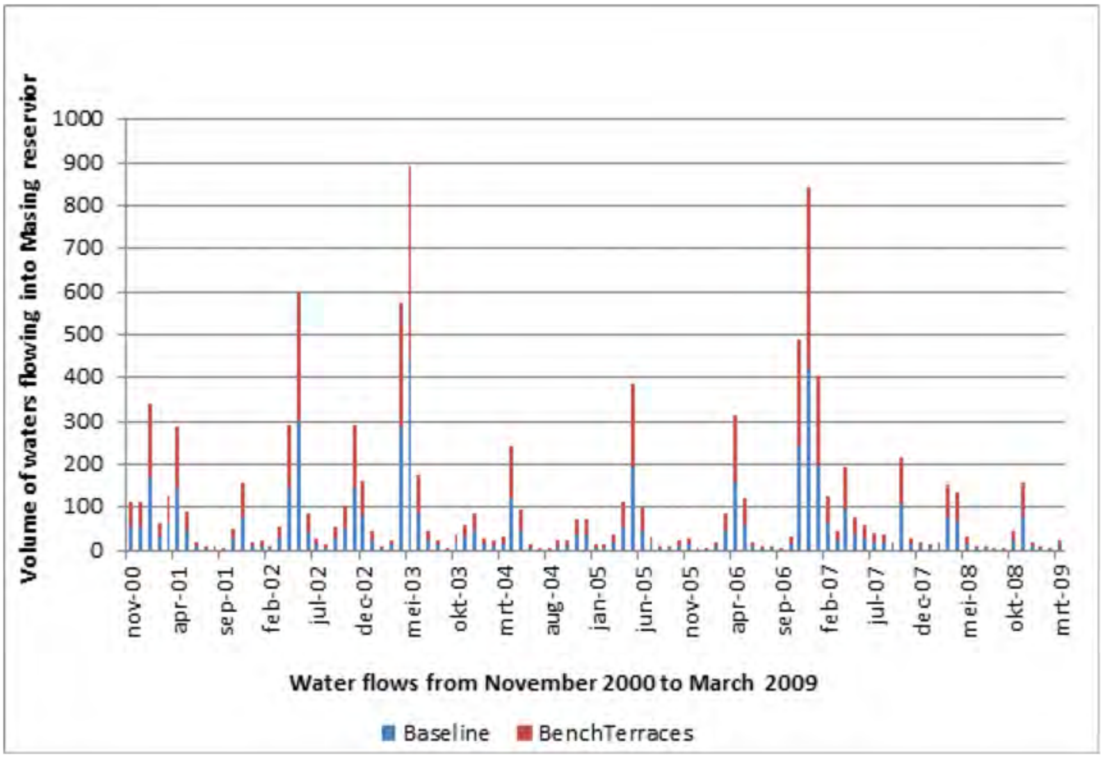


Figure 5

Volumes of water into Masinga Reservior in a normal year and if bench terraces are adopted by smallholders (Data modelled by J. Hunink, FutureWater)

4 Conclusion

Green Water Credits project interventions in soil and water conservation (*green water* management measures) in the Tana catchment area will lead to gains in Kenyan society and to its economy generally. Effects of this conservation will be felt in the provision of water for (1) human consumption around several municipalities (Nairobi and the upcoming satellite cities; namely Thika, Ruiru, Matuu) which are supplied directly from the Tana catchment; (2) irrigation in terms of longevity of water availability during the year as well as the total area under irrigation will impact the domestic food markets (small-scale irrigators supply household food and sell to the urban areas) and export markets (for example export produce from Del Monte, Kenya Wine Agencies, Kakuzi); (3) electricity generation for supply or reliable power to domestic industries and domestic consumers. Reliable power supply improves the rating of a country as a destination for foreign investors. There is therefore a case to invest in the management of *green water* resources in the Tana catchment areas in order to ensure that the lag (delay) before the benefits is minimised while the benefits that accrue to the nation are long lasting and sustainable.

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Annex 1 The costs related to water supply (irrigation, domestic and institutional consumption) from the Yatta

Yatta WASCO/Yatta small-scale irrigators water related costs

Year	**Normal year**	**Flooding year**	**Drought year**
Average length of water canal flowing with water out of 60 km	46.90	60.00	28.00
Costs of water treatment per year	**Costs (normal year)**	**Costs (flooding year)**	**Costs (drought year)**
Chlorine Quantity @KSh 230/kg)	188,830.00	335,800.00	167,900.00
Alluminium (quantity @KSh75/kg	1,779,375.00	2,737,500.00	1,157,625.00
Sodium Carbonate quantity @KSh35/kg	255,500.00	574,875.00	139,405.00
Costs of water supply per year			
Electricity	2,760,000.00	2,760,000.00	2,760,000.00
Motor vehicles maintenance (cars, bicycles and motorcycles)	600,000.00	600,000.00	600,000.00
Labour	3,021,600.00	3,021,600.00	3,021,600.00
Operations and maintenance	1,200,000.00	1,200,000.00	1,200,000.00
Fuel	3,500,000.00	3,500,000.00	3,500,000.00
Costs of emergency water supply (tankering) per year			
Fuel quantities @Ksh 108/litre	962,280.00	614,520.00	1,833,840.00
Wear & tear	400,000.00	400,000.00	450,000.00
Casual labour	73,000.00	58,300.00	112,600.00
Water supply to customers (costs based on tariffs by GoK 2006)	**Number**	**Average amount of water in m^3 served per year**	**Average costs of water per year**
Total number of domestic users served	317.00	3,650.00	127,750.00
Total number of institutions served	13.00	91,250.00	3,650,000.00
Total number of irrigators served	600.00	Can't estimate since its open system /buckets /furrows	2,500,000.00
Total Number of business served	575.00	23,725.00	830,375.00
Total Number of water Kiosks	8.00	146,000.00	1,460,000.00
Total Group connections (domestic users)	5.00	219,000.00	4,380,000.00

Yatta WASCO/Yatta small-scale irrigators water related costs			
Lost potential revenue (unmet water demand from customers)			
Number of domestic users (unserved)	400 users		161,198.74
Number of irrigators (unserved)	150 irrigators		625,000.00
Other costs			
Costs in conflict resolution (Fuel, ;lunch, car maintenance)	65,000.00	65,000.00	65,000.00
Costs in attending to complaints (meters, pipess, fittings)	93,500.00	93,500.00	93,500.00
WRMA LEVY (0.5 cents per m^3 abstracted of raw water)	120,204.00	120,204.00	120,204.00
Lease fees (paid to Tana Athi/wesreb - 10% of total revenue)	520,000.00	520,000.00	520,000.00

Source: Yatta WASCO

Annex 2 Gross margins of *sukuma wiki* (*Brassica* sp. or “kale” in English: a common and cheap vegetable) under irrigation farming in 0.128 acres of land

ENTERPRISE: Kale (*Sukuma wiki*)

Variety	Thousand heads		
Spacing	60 cm x 60 cm		
Acreage	0.128 acres		
Marketable yields	2800kg		
Price of sukuma wiki produce per Kg	KSh 8		
A: Gross income		**22,400.00**	

Variable costs (inputs)	**Quantity**	**Unit Price**	**Total costs**
Seeds	50gm	60.00/50gms	60.00
Fertilizer			
DAP	10 kg	30	300.00
CAN	40 kg	20	800.00
20:20:00	8 kg	25	200.00
Chemicals: Dimethoate	500 mls	100/200mls	600.00
Karate	100 mls	250/100mls	250.00
Transport	24 wks	60.00/2wks	720.00
B: Sub-total			**2,930.00**
Variables costs in labour-days			
Nursery Management	2.5	100	250.00
Land preparation planting & Fertilizer application	8	100	800.00
Weeding (1,2,3) & top dressing	6	100	600.00
Spraying	7	100	700.00
Harvesting and grading	24	100	2,400.00
Watering (irrigation)	10	100	1,000.00
Market preparation	4	100	400.00
C: Variable labour costs	**61.5**	**100**	**6,150.00**
D: Total variable costs (B+C)			**9,080.00**
E: Interest on working capital (15%)			1,362.00
F: Gross Margin (A-D-E)			11,958.00
G: Gross margin in KSh per acre	11958		93,421.88
H: Gross margins in KSh per hectare (conversion factor of 2.47)			**230,752.03**

Source: Yatta, Ministry of Water and Irrigation Office (Proposal for Kyamuthabia irrigation project)

Annex 3 Costs and benefits for 15 years of the 60 km canal with water in the Yatta Irrigation Scheme

	year 1	year 2	year 3	year 4	year 5	Year 6	year 7	year 8	year 9	year 10	year 11	year 12	year 13	year 14	year 15
24,991,432	22,719,711	20,652,919	18,776,063	17,069,148	15,517,180	14,107,663	12,825,603	11,658,503	10,598,866	9,634,197	8,759,497	7,962,270	7,240,018	6,580,244	5,982,949
24,991,432	22,314,849	19,923,169	17,788,901	15,882,055	14,180,138	12,660,659	11,303,625	10,094,039	9,011,910	8,047,241	7,185,037	6,415,301	5,728,036	5,113,247	4,565,935
24,991,432	21,922,484	19,230,907	16,869,216	14,797,427	12,980,550	11,386,096	9,986,576	8,761,996	7,684,865	6,740,189	5,912,973	5,188,221	4,550,940	3,991,132	3,501,300

Annex 4 Nairobi City Water and Sewerage Company Tariffs Structure (2008 – 2013)

		Tariff approved by WaSREB (KSh/m³)					
Customer Category	**Consumption Block (M3)**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Domestic/ Residential; Commercial/ Industrial; Govt Institutions; Schools	0-10	12.00	18.71	18.47	17.98	17.80	18.36
	11-30	18.00	28.07	27.70	26.98	26.71	27.54
	31-60	27.50	42.89	42.32	41.22	40.80	42.08
	More than 60	34.50	53.80	53.10	51.71	51.19	52.79
Water Kiosks	Any Amount of water	10.00	15.00	15.00	15.00	15.00	15.00
Bulk Sale to Water Service Providers for Resale	Any Amount of water	15.00	26.57	26.84	27.02	27.16	27.67

NB/ Sewerage is charged at 75% of water tariff of the corresponding consumer categories

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GWC K2	*Lessons learned from payments for environmental services*	Grieg Gran M and others 2006
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GWC K4	*Quantifying water usage and demand in the Tana River basin: an analysis using the Water and Evaluation and Planning Tool (WEAP)*	Hoff H and Noel S 2007
GWC K5	*Farmers' adoption of soil and water conservation: the potential role of payments for watershed services*	Porras IT and others 2007
GWC K6	*Political, institutional and financial framework for Green Water Credits in Kenya*	Meijerink GW and others 2007
GWC K7	*The spark has jumped the gap. Green Water Credits proof of concept*	Dent DDL and Kauffman JH 2007
GWC K8	*Baseline Review of the Upper Tana, Kenya*	Geertsma R, Wilschut LI and Kauffman JH 2009
GWC K9	*Land Use Map of the Upper Tana, Kenya:* *Based on Remote Sensing*	Wilschut LI 2010
GWC K10	*Impacts of Land Management Options in the Upper Tana, Kenya:* *Using the Soil and Water Assessment Tool - SWAT*	Hunink JE, Immerzeel WW, Droogers P, Kauffman JH and van Lynden GWJ 2011
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GWC K12	*Inventory and Analysis of Existing Soil and Water Conservation Practices in the Upper Tana, Kenya*	Muriuki JP and Macharia PN 2011
GWC K13	*Estimating Changes in Soil Organic Carbon in the Upper Tana, Kenya*	Batjes NH 2011
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