Cost and Benefit Analysis of the adoption of Soil and Water Conservation methods, Kenya

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Abstract- This paper assesses the net welfare associated with the adoption of Bench Terraces (BT), Contour Bunds (CB), and Napier Grass Strips (NGS) in the Saba Saba sub-catchment of the Upper Tana catchment in Kenya. An agro-economic survey and informal interviews were conducted in the Saba Saba sub-catchment to elicit farm level quantitative data for the Cost Benefit Analysis (CBA). Financial functions in excel were used to analyze the on-site costs and benefits of adopting the identified SWC technologies on farms with crops such as maize, coffee, and tea. In this research CBA was used as a decision tool after the computation of all cost and benefits were valued in local currency to obtain the Net Present Value (NPV) or net welfare. The results show that investment in SWC measures may not be a feasible short-term option from farmers' perspective. There is, therefore, a strong case for intervention, especially in the initial years where SWC adoption yields negative returns. Again the maintenance cost was higher for all SWC technologies. This could be attributed to poor construction techniques. Considering the sub-catchment's erosion risk severity and slope stability, Bench Terrace was found to yield relatively higher on-site net welfare.

Index Terms- Soil and Water Conservation; Bench Terraces; Contour Bands; Napier Grass Strips; Cost Benefit Analysis; Kenya.

I. Introduction

Sub-Sahara Africa's sub-humid agroecosystems experience dry spells almost every rainy season (Barron et al., 2003) with meteorological droughts occurring on the average once or twice every decade. Farming systems often suffer from agricultural droughts and dry spells caused by management induced water scarcity (Rockstrom, et al., 2007). According to Rockstrom (2003), less than 30% of rainfall is used as productive transpiration by crops in savannah farming systems in Sub-Sahara Africa (SSA) and asserts that on severely degraded land this proportion could be as small as 5%. In SSA, regardless of the fact that food production has to double to keep up with demand, per capita food production continues to decrease. This has been largely attributed to the negative effects of soil and water degradation. According to the FAO (2008), 17% of SSA's land productivity is negatively affected by soil and water degradation. Thus, crop failures usually blamed on drought might be preventable in most instances through better farm-level water management like Green Water (GW) management.

The Upper Tana catchment in Kenya is a high potential area for agricultural and water resources. However, it is characterized by catchment degradation which has led to higher and faster runoff flows and minimal infiltration. The major issues within the Upper Tana catchment include water scarcity, climate variability, river bank encroachment, soil erosion (gross erosion rate of 20.3 ton/ha/yr), siltation, poor underground recharge, and competing needs targeting scarce water resources (WRMA, 2009). Most of these problems also pertain to Saba Saba, a sub-catchment of the Upper Tana catchment. The sub-catchment suffers greatly from destruction of surface cover, high rates of erosion, and massive sedimentation (with sediment concentration of 800 mg/litre) coupled with low adoption of SWC measures (Saba Saba WRUA & WRMA, 2010). This has resulted in reduced recharge, increased surface runoff and soil erosion. The Saba Saba sub-catchment (Figure 1) is a target area for improved management of water, soil, crops, trees, and rangeland in the GWC project and has been marked "ALARM" (alarm phase) by the Water Resource Management Authority in Embu (WRMA-Embu). This is due to poor water quality, low water flows during dry spells, conflicts within the system due to poor distribution of the resource, and encroachment of wetlands and riparian areas among other reasons (Saba Saba WRUA & WRMA, 2010).

There has been substantial resource allocation to SWC from the late 90s until today by governmental agencies (e.g. WRMA, NEMA, MOA, etc) and multilateral organizations (e.g. World Bank, IFAD, PRESA, GWC, etc.) However, SWC efforts on the part of farmers have diminished in the last 10 years (Porras et al. (2007). SWC techniques remain underutilized in the Saba Saba sub-catchment for several reasons but lack of profitability (negative net welfare) at the farm level transpires as the principal (considering farmers' objectives and opportunity cost) though by no means the only important reason for the underutilization (Saba Saba WRUA & WRMA, 2010). Other reasons could be that farmers do not recognize the losses caused by soil erosion and/or that recommended SWC techniques are not effective (de Graaff et al., 2001). The question then is whether the benefit of a given SWC technique is worth the cost. This is where it becomes imperative for stakeholders to understand the financial costs and benefits associated with adopting SWC measures at farm level. Using Cost Benefit Analysis (CBA), this paper evaluates the net welfare associated with the adoption of Bench Terraces (BT), Contour Bunds (CB), and Napier Grass Strips (NGS) using farm level data from the Saba Saba sub-catchment in Kenya.

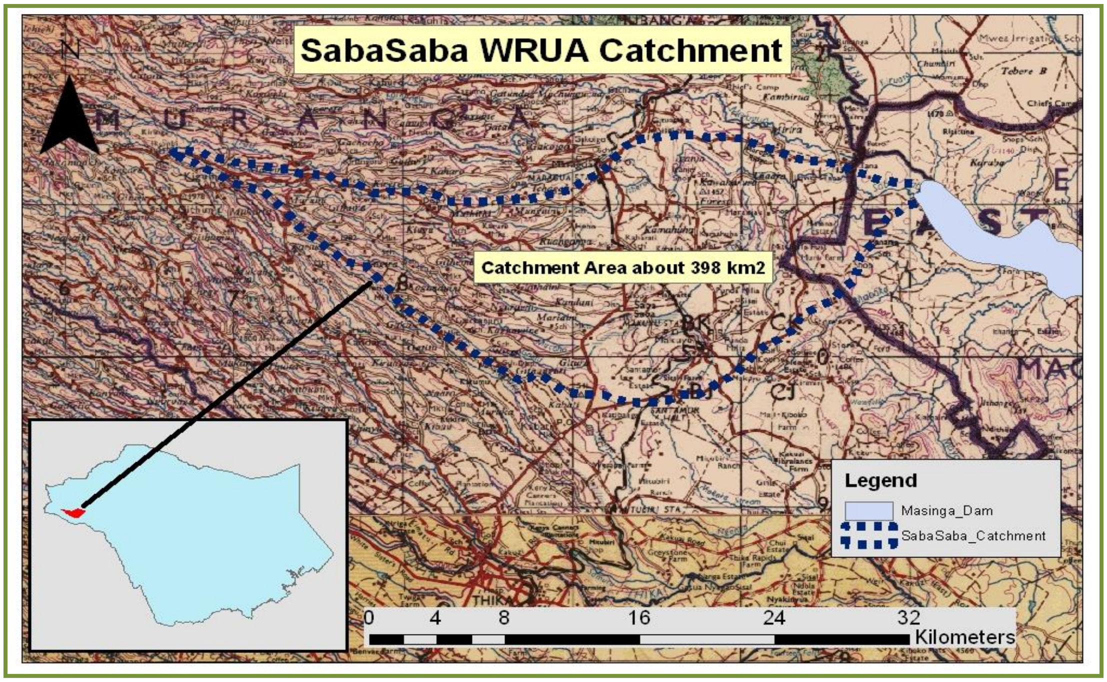

Figure 1: Map of Saba Saba sub-catchment

Source: Saba Saba WRUA & WRMA, 2010.

II RESEARCH METHOD

Cost Benefit Analysis (CBA) is a basic approach in neoclassical economics adapted by environmental economists for the evaluation of net social or private welfare from environmental remediation/projects. It is considered one of the basic postulates of applied welfare economics (Harberger, 1971). There are many justifications for this, but according to Boardway (1974) the one that appeals most to 'objective' economists is that aggregate monetary gains and losses measure the efficiency of a project. If the aggregate is positive, it implies that the gainers could compensate the losers and still be better off after the project is undertaken and vice versa. This echoed further in Mishan (1972):

> "*In general some people lose and some people gain following any economic change... the compensating variations (CV) of the gainers... may be added algebraically to the CVs of the losers... If the resulting algebraic sum is positive, gainers can more than compensate losers, and the change will realize a potential Pareto improvement. If, on the other hand, this algebraic sum is zero or negative, the economic change contemplated does not realize a Potential Pareto improvement*" (p. 317).

According to the OECD (2006), the essential theoretical foundations of CBA are: benefits are defined as increases in human wellbeing (utility) and costs are reductions in human wellbeing. For a project to qualify on cost benefit grounds its net benefits must exceed its net cost. According to de Graaff and Kessler (2009), the eventual aim of CBA is a comparison between the present value of the streams of benefits (positive effects) and the present value of all investment and recurrent costs (negative effects). In a typical CBA, the costs of the inputs are assessed and compared to the monetary estimates of total benefits that the project is expected to provide. The evaluation process consists of several stages, each paying attention to such details as totalling the benefits and costs accruing to different groups/persons in different time periods.

CBA in the context of this research was employed to evaluate the on-site losses and gains associated with adopting Bench Terraces (BT), Contour Bunds (CB), and Napier Grass Strips (NGS). The scale of the CBA in this study is farm level and the objective is a financial analysis of the gains and losses from the adoption of the three SWC measures. CBA is used here as decision tool after computing all cost and benefits valued in local currency (KES) and converted to US dollars. Figure 2 presents a framework which guides the measurement of the on-site net welfare associated with SWC technology adoption.

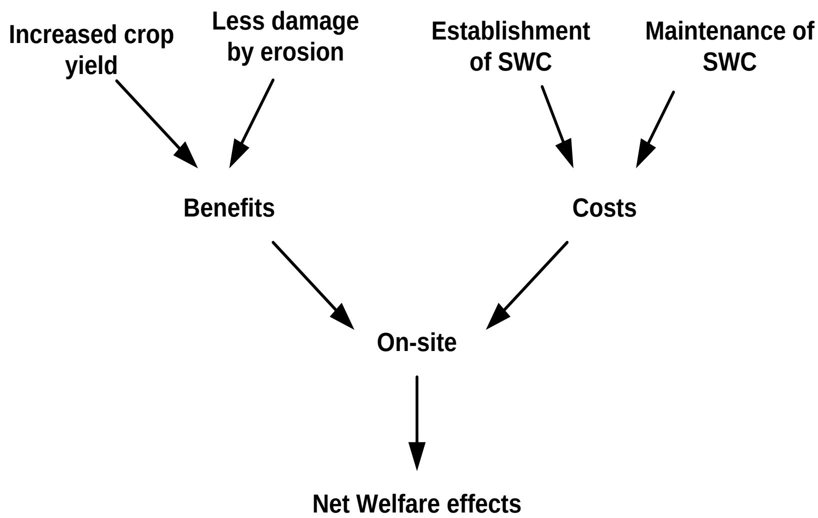

Figure 2: Measurement of Net Welfare effects of technology adoption
Source: Adapted from Stonehouse (1999).

To express the variables in this framework (Figure 2), the general sequence of analytical steps in CBA as described by de Graaff and Kessler (2009) was adapted:

A. Evaluation criteria

The selected evaluation criterion for this study was the economic efficiency/viability measure using CBA. A project that generates higher net benefits is more efficient than a project that generates less or negative net benefits. This criterion was selected considering the main objective of this research.

B. Identification of costs and benefits

This step involved the identification of economically relevant impacts. Here the question was what to count. This question is bound up in new welfare economics, in particular in the welfare function where the farmer is interested in maximizing profit. What are counted as benefits in this study were increases in quantity of goods or a reduction in damages due to soil erosion that generate positive welfare/utility. The costs include any decreases in quantity of goods (e.g. decrease in yield). The negative effects also included using up resource (inputs in production) in the project (establishment and maintenance investments).

The data from the agronomic survey was grouped in to benefits and costs. Costs included labour inputs (mandays), inputs for establishment and maintenance of each of the SWC measures (BT, CB, and NGS), the net benefit in the without SWC situation and crop production cost. The initial investment and annual maintenance costs constituted the cost on the labour and materials inputs. The production costs include labour and materials required at the following production stages: land preparation, planting, manuring, weeding, spraying if applicable, composting if applicable, fertilization if applicable, harvesting, and threshing and transportation. In this study maize, coffee, and tea were the crops considered. These are the main crops and were mostly grown on the slopes targeted by this research. To establish costs of soil erosion and the benefits of conservation, Tenge et al. (2005) and Pimentel et al. (1995) argue that erosion damage could be considered to be equal to the value of the lost crop production valued at market prices. This is comparable to the 'with and without' approach used in this study to ascertain the costs associated with soil erosion and the benefits that could accrue due to the adoption of SWC measures. Based on farmer interviews, key informants, and literature (FAO SAFR, 2002; Tenge et al. 2005) an annual productivity decline (due to soil erosion and in a without SWC case) of 3%, 2%, 1% were assumed for maize, coffee, and tea respectively.

Benefits in this paper refer higher gross margins. This was assumed to be due to the increased physical production and less damage by erosion (Figure 2 above), holding other factors constant. The major benefit of all the conservation measures considered in this analysis is the saved yield due to reduction in soil erosion. Therefore the tangible benefit from these technologies is the conserved amount of maize, coffee (berries), or green leaf tea yield multiplied by their respective unit price during the entire period. The impact of SWC techniques on the prevention of seed loss through soil erosion, retention of soil moisture, nutrients, and water is an increase in crop yields and other outputs such as fodder for the livestock that the farmer keeps. From field observations most farms were stabilized with grass risers which also served as fodder for their livestock. This study considered maximum crop yield attained to be constant for the economic lifespan of all the SWC measures. The valuation of the SWC measures was done considering the characteristics as outlined in Table 1 below. Assessment of the costs and benefits was done keeping in mind the slope and the stability of the soil in the study area. The study area is generally characterised by unstable soils with slopes ranging between 2% and 50%. The slope range considered in this study was between 20% and 40%.

Table 1: Characteristics of Soil and Water Conservation measures

SWC measures	Establishment cost	Maintenance cost	Lifespan
Bench Terraces	Very high	Relatively low (around 5% of investment)	>15years
Contour Bunds	Moderately high	Relatively high (around 10% of investment)	15years
Napier Grass Strips	Low	Relatively high (around 15% of investment)	<15 (rejuvenation in every 8 years)

C. Valuation of costs and benefits

Valuation of the stream of benefits and costs with and without conservation cases would give more accurate picture of the private and social worth of these methods. This becomes relevant in finding out farmers incentives to adopt these methods as well as to assist decision makers in designing appropriate level of support to be granted in order to accelerate adoption.

The conventional market prices approach was used for the valuation of costs and benefits. Differences (declining or increasing) in the value of output were assumed to reflect differences (declining or increasing) in crop yield between 'with' SWC situation and a 'without' SWC case. Here the changes in productivity and the changes in input levels either indicated losses or gains. All costs were converted into monetary values using their respective quantities and market prices. Labour costs were considered to be the product of the number of man-days (MD) required for a particular task and the market price of labour per day. Quantities and market prices were obtained from field interviews and were crosschecked from key informants. The average MD was the equivalent of six working hours in the farm. The benefits were also converted into monetary values by multiplying their respective quantities by their market value. In CBA some adjustments are often made to the valuation of labour inputs. In the case of skilled and semi-skilled labour it can generally be considered that the market wage rate reflects the opportunity cost. However, unskilled labour which also includes farm labour tends to experience unemployment in developing countries. As a result, the opportunity cost of unskilled labour, that is the value of production that could be achieved by the labour elsewhere in the economy, can assume a lower value (even close to zero) in a financial analysis (Bojo, 1999). Farmers and their families work often at opportunity costs below market wages. For the financial analysis in the present study, the opportunity cost of farm labour is assumed equal to 80% of the local wage rate for hired casual labour in the study area, justifying the limited off farm opportunity of the farm labour in the study area.

D. Choice of time horizon and discount rates

The effects of discounting are important for any project that involves immediate expenditures and also have benefits that do not accrue until sometime in the future like in the case of the SWC methods analyzed in this study. In this study, the discount rates were based on the interest rates payable by farmers on bank loans. Farmers in this study area received loans from banks and cooperative groups at the rate of 17.5% basically on group accountability basis. This interest rate was used in this study after deducting average annual inflation rate of 9% in the agricultural season under consideration. The discounting of future costs and benefits to their present values was therefore done using a discount rate of 8.5% (real interest rate). The specification discount rates and time horizon was done simultaneously since the two interact in their effects on the results. The study considered the physical lifespan of the investment in SWC from the perspective of the farmers. The lifespan for BT for instance is, in general, considered to be between 25 to 30 years but the average lifespan, as given by the farmers was 15 years implying that they reinvested (rejuvenation) every 15years (Table 1).

E. Appraisal indicator

The Net Present Value (NPV) and the Internal Rate of Return (IRR) are the main appraisal indicators used in this analysis though the Benefit Cost ratio (B/C ratio) is also shown just for comparison purposes. These are the commonly used decision criteria for determining profitability of a project (Kuyvenhoven & Mennes, 1989). The NPV is defined as the present worth of the net benefits of a project. In financial analysis, it is considered to be the present value of the net income stream accruing to the entity undertaking the project. SWC measures with NPV equals to or greater than zero are considered profitable and economically robust to farmers. In FAO SAFR (2002) this is mathematically expressed as (equation 1):

$$NPV=\sum (B_t-C_t) / (1+i)^t > 0 \qquad \text{(equation 1)}$$

where B_t is the gross benefits, C_t the total cost, t is the time horizon, and 'i' is the discount rate (conceptually it is the discount rate but during calculation the interest rate is taken).

The Internal Rate of Return (IRR) is the discount rate at which the total discounted cash benefits expected from a project equal the total discounted cash costs required by the investments (FAO SAFR, 2002). The IRR can also be described as the rate of growth of an investment which is also comparable to the opportunity cost of capital or the borrowing rate of financing the project. When the IRR is greater than the discount rate, then the investment is worthwhile. The IRR in this study was generated in Microsoft Excel using the IRR financial function. Without excel, IRR could also be calculated manually using the following formula (equation 2) which is more of a trial and error method (FAO SAFR, 2002):

$$IRR = ldr + \frac{(hdr - ldr) \times NPV \text{ at } ldr}{(NPV \text{ at } ldr - NPV \text{ at } hdr)} \quad \text{(equation 2)}$$

where:
IRR = Internal Rate of Return
hdr = higher discount rate
ldr = lower discount rate
NPV = Net Present Value

F. Sampling and data collection

The unit of analysis in this study was formed by heads of Household who were farmers with or without Bench Terraces (BT), Contour Bunds (BT), or Napier Grass Strips (NGS) and who had farms on slopes between 20% and 40%. The choice of SWC measures was based on popularity of the measure. After discussions with Saba Saba Water Resource Users Association (WRUA) and preliminary field survey, it was established that BT, CB, and NGS were the most preferred and popular. In total seventy five (75) farmers were interviewed. This figure was purposefully selected because detailed information was needed for a Cost Benefit Analysis. The Saba Saba sub-catchment is divided into upper, middle, and lower and further subdivided into locations (Table 2, below). Based on these divisions and locations the fieldwork was structured in a way that information or data sought would be representative of the sub-catchment. With the help of the Saba Saba WRUA executives, 30, 25, and 20 respondents were selected and interviewed from the lower Saba Saba (which is the biggest of the divisions), middle and upper respectively. The data, during cleaning and coding, was grouped by crop type and SWC type (Table 3). This was done to give an idea about which conservation method is popular with which crop type. For instance, BT is predominantly adopted by coffee farms and this could be attributed to the fact that coffee farms are mostly found on higher grounds with relatively steeper slopes. This regrouping also helped the discussion on the relationship between characteristics of smallholder farmers and the type of SWC methods they adopted.

Table 2: Respondents by Divisions and Locations in Saba Saba catchment

Division	Locations	Sample size
Upper Saba saba	Marriira, Kariua, and Kigumo east	20
Middle Saba saba	Muthithi, Kahumbu, and Gaichanjiru	25
Lower Saba saba	Kamahaha, Kambiti, and part of Makuyu	30
Total		**75**

Table 3: Respondents by SWC measures and crop type

Crops\SWC	BT	CB	NGS	Without SWC	Total
Maize	7	9	6	7	29
Coffee	21	7	0	5	33
Tea	11	0	0	2	13
Total	39	16	6	14	75

An agro-economic survey was conducted on selected farms. A survey questionnaire was administered (by the researcher and field assistance) to selected farmers within the Saba Saba catchment. Data on the following farm level issues were elicited from smallholder farmers within the sub-catchment: household characteristics and labour resources; farm land characteristics; crop yield and prices; crop production (i.e. investments on crop production), farmers' knowledge of soil erosion; and soil and water conservation practices (investments on SWC). This survey obtained the necessary quantitative data for the financial CBA. The financial CBA aided the discussion on the costs and benefits associated with the adoption of Terraces (T), Contour Bunds (CB), or Napier Grass Strips (NGS). Data solicited from farmers were analysed using SPSS and Microsoft Excel. The SPSS was used for the tabulation of frequencies for the financial cost benefit analysis in Excel.

III RESULTS AND DISCUSSION

This section presents and discusses the result of the study. It covers such issues as household and farm characteristics and results of the cost benefit analysis.

A. Household and farm characteristics

The basic characteristics of farmers and their farms were analysed (Table 4). Majority of respondents used BT and the least adopted SWC measure was NGS. The uneven distribution of respondents among SWC measures is because the survey was done on the basis of the divisions and locations in the sub-catchment and not according to SWC technologies.

Table 4: Household and farm characteristic (mean values)

Variables	BT N=39	CB N=16	NGS N= 6	Without SWC N=14
Household Characteristics				
Household size (persons)	5.2	5.3	4.6	3.2
Age (year)	53	52	52	49
Gender				
Male	69	56	57	45
Female	31	44	0.4	55
Level of Education				
Primary	42	40	0.4	21
Secondary	25	15	0.1	07
Tertiary	13	08	0.06	00
None	20	37	0.4	72
Farming experience (years)*	30	23	19	17
Farm Characteristics				
Farm size (ha)	2.4	1.1	0.6	0.6
Soil texture				
Sandy loam	56	62	55	57
Clay loam	44	38	45	43
Fertility Status				
Low	22	37	57	74
Medium	60	51	35	26
High	18	12	08	00

**Number of years in farming, CB=Contour Bunds, NGS=Napier Grass Strip, N= number of respondents*

Farm household size

Household in this study refers to individuals living in the same dwelling. That is a basic residential unit in which economic production, consumption, inheritance, and child rearing, and shelter are organized and carried out. The household may or may not be synonymous with family. The household size of those who invested in SWC measures was larger than those who did not adopt any measure (Table 2). In rain-fed agriculture, much of farm work is done with family labour as a result the size of a family to some extent relates directly to the availability of farm labour. For instance with Bench Terraces, Juma, et al. (2009) found in the semi-arid lands of Kenya that a marginal increase in household membership increased the probability that the household will adopt terracing as a measure of soil conserving and conditioning effort. This is not surprising because terracing is labour-intensive and would favour larger households. Therefore, when households rely on family labour, in the case of Saba Saba, a larger household becomes an obvious positive factor in the adoption of terrace adoption. The table 2 shows that the average household size for those with SWC measures is larger than those without SWC measures. This could imply that those who adopt SWC measures have access to more family labour than those without.

Age and Gender

This paper considers only the age and gender of the household heads, who in Kenya make major decisions (including farming decisions) within the household set up (paternalistic culture). Household heads who invested in SWC measures, on the average were older than those who did not (Table 4). Many researchers agree that the age of a household head may have an ambiguous influence on the adoption of SWC technologies. Younger generations, as compared to older ones, may be more inclined to adopt new techniques as they learned these from school and might even have a longer time horizon. They have more understanding of soil erosion problems and thus might have more interest in SWC. However older farmers may also have gained more knowledge through their actual experiences in farming and thus become knowledgeable in handling soil erosion problems. Further, older farmers may have saved and are more motivated to leave something of lasting value to their children, hence may invest in more long term asserts such as BT.

As could verified in table 4, more male households heads adopted SWC measures while females dominated the without SWC case. Males have a higher chance of adopting soil conserving measures compared to their female counterparts. This is perhaps because smallholder agriculture in the study area is dominated by men and probably because men control more resources and therefore male-headed households have a better chance to invest in SWC measures (Mugonola, et al., 2013).

Education

There are three levels of education existing in the study area. These are taken in succession: eight years of primary education, four years of secondary, and four years of tertiary education. For education, Pender and Kerr (1998) observed in the semi-arid areas of India that investment in SWC technologies increased by 25% of the average investment level for every additional year of education. This could be an explanation for the fact that most the respondents who did not adopt any SWC measure (72%) had no formal education (Table 4).. From informal discussions with key informants, a better-educated household head has more realistic perceptions about soil erosion problems and more knowledge on SWC and therefore is likely to participate in conservation activities. From the discussions with Saba Saba WRUA executives, it was intimated that farmers around lower Saba Saba sub-catchment were better educated than upstream farmers because the downstream area is closer to Muranga and Maragua, where more schools are available. If this assertion holds, then education does not positively influence the adoption of SWC measures as argued by Pender and Kerr (1998). The downstream portions of the Saba Saba sub-catchment are the most affected by soil erosion and the farmers are less inclined to SWC adoption.

Farming experience

By farming experience the paper refers to the number of years a household head has been in farming. The average number of years of farming experience for farmers with BT was 30 years followed by farmers with CB (23 years). Farmers who adopted NGS had on the average 19 years of farming experience while farmers without any SWC measure had lesser experience (16 years). Looking at this trend, it could be argued that the more experienced a farmer is the more likely it is for him/her to adopt longer lasting techniques like BT.

Average farm size

Average parcel size in this study reflects the amount of landholding that a farmer could use as an input in production. In this study the average farm size for farms with BT was 2.4 hectares followed by farms with contour bunds (1.13ha). It has been argued in several literature that the larger the landholding of a farmer the more likely it is for he/she to invest in SWC technologies especially for structural measures (Dellink & Ruijs, 2008; Mengstie, 2009; Semgalawe, 1998). This is usually because farmers with relatively larger landholdings can spare land areas for such SWC measures.

Soil texture and fertility status

With to soil texture in the Saba Saba sub-catchment, the proportion of farm lands with sandy loam soils was higher under all farms with SWC measures and the without SWC measure category. Farm land fertility was classified into three categories: low, medium and high. From table 5, majority of farmers who used BT (60%) had soils of medium fertility while 72% of those who did not invest in any SWC measure reported low fertility. The farmers categorized the fertility of their farms considering the yield holding other influencing factors constant. Farmers want to take better care of fields that give better yield (Dellink & Ruijs, 2008) and this could be an explanation why fields with SWC technologies have better soils than fields without SWC measures.

B. Cost Benefit Analysis of the adoption of Soil and Water Conservation Methods

The results of the CBA are discussed in this subsection. The establishment and maintenance cost and the annual cash flows from the adoption of the three SWC methods are presented below. The economic viability of the three methods is also discussed.

Establishment and maintenance cost of Soil and Water Conservation Methods

The establishment and maintenance cost of all three Soil and Water Conservation measures is the product of the “mandays” and the market wage of labor per day. The time needed for the establishment of SWC is very important because it influences farmers’ technology adoption decisions. It is important to note that labor requirements for construction of SWC measures increase with increasing slope and the level of stability of soil (Tenge et al. 2005). In the context of this research, farms are situated on slopes between 20% and 40% with unstable soils.

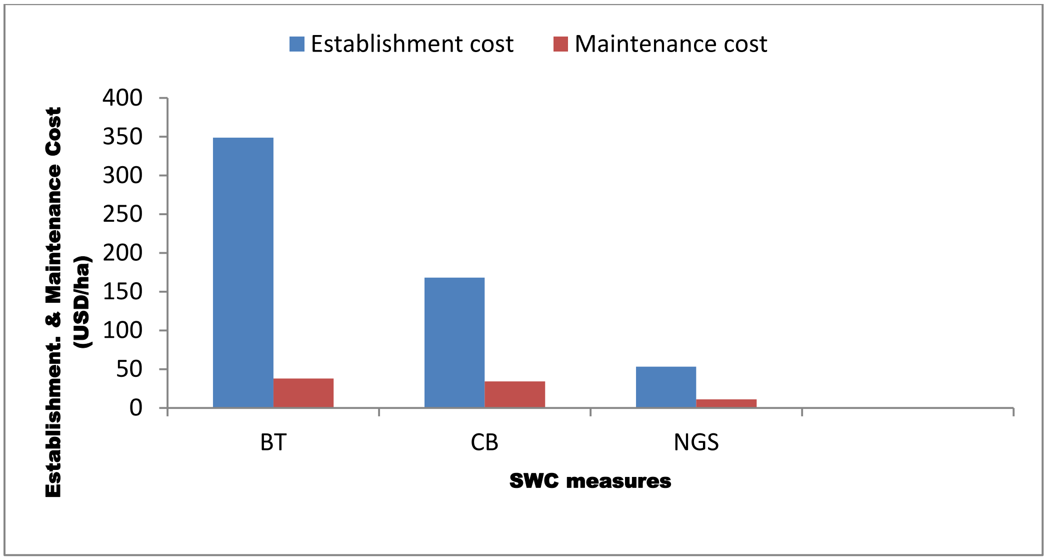

Figure 3: Establishment and maintenance costs of BT, CB, and NGS

BT are relatively expensive to construct (USD 349) but relatively cheaper (11% of establishment cost) to maintain (Figure 3, above). According to Tenge et al., (2005), time needed to establish BT ranges from 66 to 592 man-days per hectare (MD/ha) depending on the slope and stability of the soil. Based on farm level data, 279 MD/ha is required for the establishment of BT. On the average, a man-day (MD) is valued at USD 1.25 with food provided or USD 1.5 without food. NGS is the least expensive in terms of establishment cost (USD 53) but is relatively the most expensive (21% of establishment cost) to maintain. The time needed for NGS establishment is 42 MD/ha which falls within the range (7 to 59 MD/ha) established by Tenge et al. (2005). Annual maintenance cost of CB accounts for about 19% of the establishment cost (USD 168). According to FAO SAFR (2002), the annual maintenance costs of technologies, if implemented properly, should range from 5% to 10% of implementation cost. As such it could be concluded that the high maintenance cost associated with these three SWC measures is as a result of poor implementation. If the technology is not properly constructed, it is only logical that one will need more funds and time for its maintenance. Training farmers on construction of SWC measures could be a solution in addressing this problem.

Annual cash flow analysis of soil and water conservation methods

This section looks at the entire investment period and whether the investment accumulation is enough to justify the cost. According to the FAO SAFR (2002), farmers would rather focus on the actual money they will get by adopting a technology in the short term than consider the long term economic justification for such investments. The time SWC measures start to produce benefits differ among measures and crops. As a result it is critical that promoters and adopters are aware of the period after which the respective technologies begin to yield benefits and under which crop. Figures 4, 5, and 6 below presents the annual cash flow over a 15 year period for the three SWC measures (BT, CB, & NGS) with three different crops (Maize, Coffee, & Tea) on slopes between 20% and 40% with unstable soils. The research established that some Tea farms used BT but it should be noted that this is not the norm in the sub-catchment, as tea planting is already considered a means of conserving the soil.

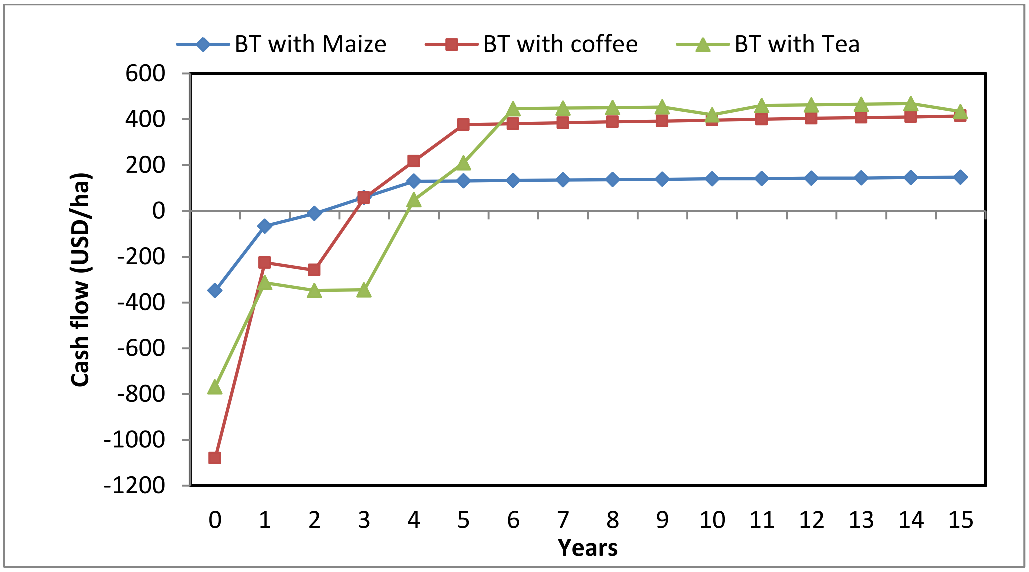

Figure 4: Cash flows from investments in BT with all three crops

It takes at least two years before a farmer can realize a positive cash flow from BT (Figure 4, above). In the Muranga District, Ekbom (1995) found that net benefits in the first three years were highest on fields without SWC measures. Tenge et al. (2005) observes a similar trend in Tanzania where positive cash flows were only realized from the second year onwards. This trend could be attributed to the high initial investment cost and initial decline in yield as a result of loss of cultivable area and soil disturbances during construction. It must be mentioned that the number of years before a farmer gets a positive net benefit differs by crop. During this waiting period, in terms of BT with maize, the sum of USD 67 and USD 12 are required to sustain the farmer in the first and second years respectively whilst for BT with coffee USD 226 and USD 259 are required to sustain the farmer in the first and second years respectively. For BT with tea, USD 313, USD 348, and USD 345 are needed for the sustenance of the farmer in the first, second and third years respectively. Tea takes three years (establishment phase) before bearing. After bearing, every three to five years the farmer undertakes pruning/rejuvenation. In this study these two issues (establishment phase and rejuvenation periods) were considered in the financial analysis. The farmers use close to 9% (USD 38) of the establishment cost of Tea for rejuvenation every three to five years. Pruning is often done in rotation for different parts of the Tea farm, the whole Tea farm is not pruned at the same time. The initial negative returns to investment could serve as a hindrance to the adoption of BT in the Saba Saba sub-catchment since most of the households suffer financial constraints. In this regard financial incentives in the form of credit or coupons for the purchase of farm tools and seeds are possible solutions.

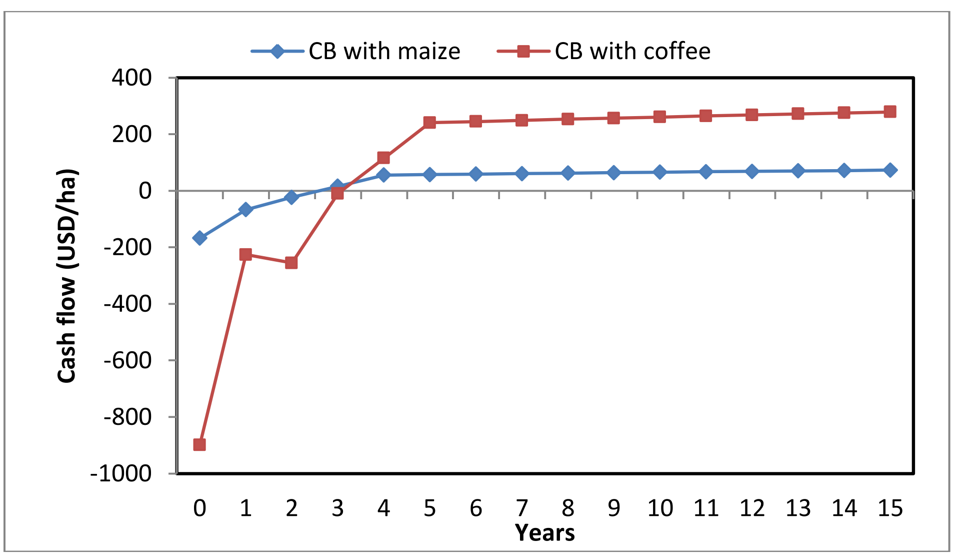

Figure 5: Cash flows from investment in CB with maize and coffee

Coffee farmers who adopted CB only make positive net benefits in the fourth year which implies that the farmer requires USD 266, USD 255, and USD 9 for sustenance in the first to third years respectively (Figure 5, above). Unlike farmers who adopt CB on their coffee farms, maize farmers with CB start to realize positive net benefits in the third year of production. As a result they require an external source of sustenance for the first two years of production. Maize farmers with CB require USD 67 and USD 23 in the first and second years respectively for sustenance. CB is not so financially beneficial on maize farms (as compared to CB with coffee farms) in the Saba Saba sub-catchment. From discussions with WRUA executives NGS and CB did little in reducing soil erosion in the middle and lower Saba Saba sub-catchment. Erosion risk severity is relatively higher in these parts compared to the Upper Saba Saba sub-catchment. As a result, farmers in these areas are encouraged by WRMA and the Kenya Ministry of Agriculture to adopt combinations of SWC measures.

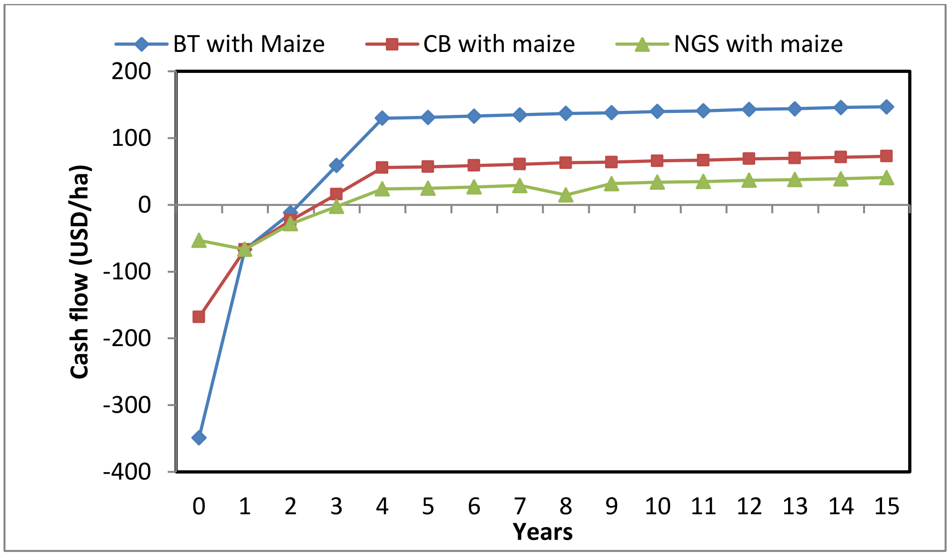

Figure 6: Cash flows from investments in BT, CB, and NGS with maize

Though NGS has the lowest establishment cost, there is still a negative return in the first three years (Figure 6 above). This could be attributed to low increase in crop yield (due to adoption of NGS) considering the slope and the stability of the soil. During these three years of waiting the farmer requires USD 67, USD 29, and USD 3 in year one, two, and three respectively for his/her sustenance. It could also be seen from Figure 15 that even after overcoming the initial establishment cost, the cash flow from NGS is still lower than the case with BT and CB. Based on its low establishment cost and relatively short term benefits, it could be concluded that NGS are constructed as steps towards the establishment of more resilient SWC technologies. NGS in the Saba Saba sub-catchment has a low return on investment but when combined with BT or CB (as explained by key informants in middle Saba Saba) has a high tendency of increasing crop yield tremendously. NGS is adopted mainly on maize farms in the lower Saba Saba sub-catchment where soil erosion is relatively intensive. Promoting the adoption of more physically effective SWC technologies (e.g. BT with grass risers) and financially efficient SWC measures (Table 5) in this part of the catchment could be a solution to the high erosion rate.

Net welfares associated with the adoption of Soil and Water Conservation methods

During the interviews the majority of those who adopted SWC measures stated that their yield had increased and that the problem of soil erosion had reduced. Farmers in the Saba Saba sub-catchment could use four different financial indicators (separately or combined) to inform their choice of SWC measure. These indicators are gross margin per Man Day (GM/MD), the NPV, the IRR, and the B/C ratio (Table 9). For maize farms on slopes 20% to 40% with unstable soils, the results indicate that the most financially efficient option is the adoption of BT (considering all four indicators). Relatively, the less favorable option in this regard is NGS. Considering the physical conditions of these farms, NGS is less capable of ameliorating/reducing the impact of soil erosion and improving green water on its own, unless used to complement other SWC measures.

Table 5: An overview of the Cost Benefit Analysis

Crop type		BT	CB	NGS
Maize (kernel)	*Gross Income	681	521	423
	*Total cost	406	370	328
	*Gross margin	275	150	95
	*Gross margin/MD	2	2	2
	*NPV (8.5%)	415	127	26
	IRR (8.5%)	18%	13%	9%
	B/C	1.43	1.31	1.18
Coffee (Berries)	*Gross Income	1092	917	
	*Total cost	469	434	
	*Gross margin	623	483	
	*Gross margin/MD	4	3	
	*NPV (8.5%)	670	46	
	IRR (8.5%)	14%	9%	
	B/C	1.49	1.04	
Tea (green leaves)	*Gross Income	1294		
	*Total cost	513		
	*Gross margin	781		
	*Gross margin/MD	3		
	*NPV (8.5%)	420		
	IRR (8.5%)	12%		
	B/C	1.38		

**All in USD*

For coffee farms with similar conditions, again BT is the most financially efficient measure. It has relatively higher gross margin/MD ($4), NPV ($670), IRR (14%), and B/C ratio (1.5) compared to CB on coffee farms which has lower values. Bench Terraces profitability over CB and NGS in this analysis could be attributed to its huge influence on crop yield especially on steep slopes with unstable soil (Table 6). BT has the highest internal rate of return (on maize and coffee farms) which suggests that farmers who are able to adopt BT stand a better chance of recovering their investments than with CB and NGS. Only a few of the tea farms had a SWC measure and these few adopted BT with and without grass risers. Tea is in itself a cover crop which reduces the detachment effect of rain drops (but was not considered in this study as a SWC measure). This could be the reason why most tea farmers did not adopt SWC measures but relied on the canopy created by the tea plants. Considering the decision criterion for NPV and IRR, BT is a financially viable for tea farmers (at 8.5% discount rate). Linking these results to the framework under the research method section, BT yields the highest net welfare considering the existing conditions (erosion risk severity, slope, soil stability).

IV CONCLUSION

The Saba Saba sub-catchment is one of the worse affected areas in the Upper Tana catchment in terms of soil erosion. Upstream (smallholder farmers) and downstream (e.g. large irrigation farms) users acknowledge the existence of this problem. Currently used SWC measures in the Saba Saba sub-catchment are Bench Terrace, Contour Bunds, Funya Juu Napier Grass Strips, Mulching, and Cut-off Drains. The most common among these are Bench Terrace (mainly in the upper and middle Saba Saba), Contour Bunds (mainly in the middle and lower) and Napier Grass Strips (mainly in lower).

The investment needed for the establishment and maintenance of these SWC measures is critical to farmers' technology adoption decisions. The required investment varies with the type of SWC technology. In the Saba Saba sub-catchment Bench Terraces are relatively expensive to establish but relatively cheaper to maintain compared to Contour Bunds, and Napier Grass Strips. Contrarily, Napier Grass Strips are relatively cheaper to construct but relatively expensive to maintain. In general, all three measures have high maintenance costs which are as a result of poor establishment.

The time Bench Terrace, Contour Bunds, and Napier Grass Strips start to yield benefits differ among crops. As a result it is important for adopters and promoters of SWC technologies to be aware of the period after which respective measures produce benefits. During this waiting period the farmer requires a certain amount of capital for sustenance which also varies with SWC measure and crop type. The initial zero or even negative returns to investment could be an obstacle to continued adoption of the respective SWC measures in the sub-catchment. Thus, the investment in SWC measures may not be a feasible short term option from farmers' perspective. This is a strong case for intervention especially for the initial years where SWC adoption yields negative returns. Considering the NPV and IRR of the respective technologies, Bench Terrace yields the highest net welfare, followed by Contour Bunds and Napier Grass Strips in that order regardless of the crop type.

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