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Financial Benefit-cost Analysis of Terraces in Maize-pigeon pea Intercrop in Semi-arid Areas of Kenya.

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Abstract

Farming households depending on rain-fed agriculture in semi-arid lands of Kenya have been adversely affected by climate change. Many impacts such as increased land degradation and soil erosion, changes in water availability, reduced farm productivity need be addressed. Fanya juu terraces have been promoted for soil and water conservation and as an adaptation strategy to climate change in semi-arid lands of South Eastern Kenya; however, the efficiency and profitability of the terraces has not been explored. Survey data to determine the efficiency of terraces was gathered from Machakos, Makindu and Mutomo Sub-counties. The net present value, internal rate of return and benefit to cost ratios were used to estimate the efficiency of fanya juu terraces in maize and pigeon pea production. The results show that adoption of fanya juu terraces as an adaptation strategy is feasible. The study recommends policy interventions that increase farmers' adoption of fanya juu terraces through improved access to agricultural extension services and credit facilities. Improvement of market environment is also required as an incentive to adopt the adaptation strategies whose yields could have easy access to a functioning market to enable generation of maximum farm revenue for sustainable operation and maintenance of farm activities.

Keywords: Adaptation to climate change; financial benefit-cost analysis; Fanya juu terraces; maize-pigeon pea intercrop; Semi-arid lands

Introduction

Farming households depending on rain-fed agriculture in semi-arid lands of Kenya have been adversely affected by climate change (GoK, 2010). Changes in mean rainfall and temperature as well as increase in extreme events unfavourably affect agriculture (IPCC, 2007; Niang et al., 2014). Many impacts such as increased land degradation and soil erosion, changes in water availability, reduced farm productivity and disasters need be addressed in rain-fed agricultural systems in semi-arid Kenya (ILRI, 2007; GoK, 2010). To reduce land degradation, Fanya juu terraces have been promoted both as soil and water conservation practice and adaptation strategies to climate change in semi-arid lands of South Eastern Kenya where maize and pigeon pea are some of the staple crops grown (Recha et al., 2013; Matere et al., 2016).

Fanya juu terracing is one of the in in-situ rainwater harvesting technologies that have been recommended to retain excess water during rain storms and curb soil erosion (Nyangena, and Köhlin, 2008; Onduru and Muchena, 2011; Omoyo *et al.,* 2015) and as an adaptation strategy to climate change (Recha et al., 2013; FAO, 2014; Matere et al., 2016), however, the efficiency and profitability of adopting the technology has not been explored.

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Farmers adopt the terraces but with minimal annual maintenance of the structures (Bett, 2004; Ogada *et al.*, 2010); the soil and water conservation efforts by farmers have diminished in the past ten years (Porra et al., 2007). Establishment of terraces has also been a constraint to some resource poor farmers in form of capital and labour requirement or indirectly through foregone production (Nyangena and Köhlin, 2008). This leaves a critical question on whether the benefits of terraces are worth the cost. Some studies conclude that profitability of soil and water conservation (SWC) structures is highly situational specific and depends on ecological characteristics and crops grown (Shiferaw and Holden, 2001; FAO, 2014; Atampugre, 2014). This study takes in consideration a specific ecological zone and major staple crops grown and analyzes the profitability and efficiency of maize-pigeon pea production on fanya juu terraces in semi-arid areas of South Eastern Kenya.

Methodology

The study compares the benefits and costs of *fanya juu* terraces in maize and pigeon pea production to inform decision makers on the likely efficiency of adaptation investment. Benefit-cost analysis (BCA) of *fanya juu* terraces was calculated by comparing the cost incurred and the benefits generated from establishing and maintaining the terraces in maize and pigeon pea production which were expressed in monetary terms. Net Present Value (NPV), Benefit Cost Ratio (BCR) and Internal rate of return (IRR) methods were used to estimate the efficiency of the adaptation strategy.

The study identified costs as inputs used in production, establishment, and maintenance of the terraces. Any decrease in crop yields was also considered as a cost. The layout and establishment cost constituted the cost on labour and material inputs involved. The production costs included labour charges and materials required in land preparation, planting, manure and inorganic fertilizer application, weeding, harvesting, threshing and transportation of the farm produce and the annual maintenance of the terrace. Benefits were identified as increase in crop yield attributed to adoption of terraces as an adaption strategy to climate change. Benefits were also estimated through gross margins. The impact of terracing on retention of soil moisture; nutrients and soil were assumed to be reflected in the increase in crop yields and other outputs such as fodder for the livestock.

Costs were converted into monetary values using their respective quantities multiplied by their market prices. Labour costs were valued by the number of man-days (MD) required for a particular task at the local market price of Kenya shillings (KES) 200 per man-day. Quantities and market prices were obtained from field interviews and were cross-checked from key informants. The average MD was the equivalent of six working hours on the farm. The benefits were also converted into monetary values by multiplying the quantities of yield in maize, pigeon pea; the vegetation/grasses planted on the embankments used as fodder and the crop residues multiplied by their respective market prices.

The net present value (NPV) is the difference between the present value of the benefits and the present value of the costs. An adaptation option with an NPV greater than zero is acceptable as this is an indication that the discounted benefits exceed the discounted cost (Gittinger, 1982). The Net Present Value was calculated as:

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

where: $B_t = \sum_{i=1}^{1} P_i Q_i$ and $C_t = \sum_j^J P_j R_j$; B_t is the benefit of the adaptation option in time period t, P_i = is price of output *i*, Q_i = quantity of output *i* and C_t is the costs of the adaptation option in time period t, P_j is the price of input *j*, R_j is the quantity of input *j*. r is the discount factor and T denotes the time horizon.

The study assumed a discount rate of 12 percent and further used a rate of 10 and 14 percent for comparison and sensitivity analysis. Farmers in the study area who got loans from the commercial banks received at an interest rate of 18 percent per annum, while the inflation rate in the country at the time of the study was 6 percent.

Discounting of future costs and benefits to their present values was therefore done using a discount rate of 12 percent (real interest rate). The discount rate is used reflects the time preference for the farmer against the opportunity cost of capital. Following De Graaf (1996) and Atampugre (2014), the study assessed the costs and benefits over a 15-year as the life span period of the terraces. The study assumes that no additional damage occurs as a result of the proposed adaptation option.

The farming household that had not adapted to climate change during time t generated revenue estimated as: $\pi_t^E = PY_t^E - C^E Y_T^E$, where PY_t^E is the revenue generated from crop yield, crop residues like maize stovers and pigeon pea stalks (Y_i) in year t that was multiplied by the price (P_i) for the considered crop (*i.e.* maize, pigeon pea), while $C^E Y_T^E$ is the corresponding cost of production. The returns obtained from adopting *fanya juu* terraces in maize and pigeon pea production (here after referred to as adaptation option) in any given period was thus given by: $\pi_t^C = PY_t^c - C^C Y_t - C_t^{ADPOP} + PZ_t^{ADPOP}$; where, C_t^{ADPOP} denotes the costs for establishing and maintaining the adaptation option; Z_t^{ADPOP} denotes any additional yield, which could be, realized on the adaptation option structures in year t, especially from crop residues and grass established on the terrace embankment. The net benefit obtained from investing in the adaptation option in any given period was expressed as:

$$\pi_t = \pi_t^C - \pi_t^E, t = 1, \dots T = \sum_{t=1}^{T} (\pi_t^C - \pi_t^E) / (1 + r)^t \quad \dots\dots (2)$$

The internal rate of return (IRR) in the study refers to the maximum interest rate that a farming household could pay for the resources used in establishing terraces on farm if the household is to recover its investment and operating costs and still breakeven. It is the discount rate that makes the NPV equal to zero; the higher an option is, the more desirable it is (Gittinger, 1982). The IRR is calculated as:

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

Where: r is the discount rate and the other parameters are as defined above.

The benefit-cost ratio (BCR) is the ratio of the present value of the benefits to the present value of the costs. Benefits and costs are each discounted at a chosen discount rate. The benefit-cost ratio indicates the overall value for money of a project; in this study it shows the returns that a Kenya shilling invested in the adaptation would bring to the farming household in present value terms. If the ratio is greater than 1, the option is acceptable. Following Gittinger (1982), the BCR was computed as:

$$BCR = \frac{\sum_{t=1}^{T} \frac{B_t}{(1+r)^t}}{\sum_{t=1}^{T} \frac{C_t}{(1+r)^t}} > 1 \quad \dots\dots (4)$$

Sensitivity analysis of the results derived from the benefit-cost analysis was conducted to test the extent to which the result of the assessment is affected by changes in key parameters like the discount rate (r). A range of discount rates was applied to test the validity of the results and ensure that the discount rate chosen was not close to a point that would reverse the decision and require further analysis. The appropriate discount rates used were based on the interest rates payable by a farmer for the appropriate commercial bank loan.

Data Collection

The study used both primary and secondary data. Primary data was gathered through a semi structured questionnaire. Maize and pigeon pea producing divisions in the Machakos, Makindu and Mutomo sub-counties were purposefully selected. Multistage sampling technique was employed to select wards from which the villages were selected. A simple random sampling technique was used to select 300 households with 100 households from each of the three countries. Key informants from the Ministry of Agriculture were purposively selected for interviews.

The questionnaire delved into the household characteristics specifically on age; gender, level of education and years of farming experience of the household head and family size. Farm characteristics included farm size, slope of the farm, land tenure, crops grown on farm, labour resources whether hired or family labour, whether farmer had *fanya juu* terraces on farm and reason for adopting them, cost of production, crops yield, quantities of crop residue and prices of commodities produced on farm. Access factors investigated were farmers' access to agricultural extension services, climate change information, and credit facilities. Farmers were also asked if they belonged to any farmers association.

Results and Discussions

This section presents and discusses the descriptive statistics and gross margins of the adopter and non adopters of fanya juu terraces in maize and pigeon pea production. The Benefit- cost analysis results are also presented.

Table 1 gives the descriptions of both adopters and non adopters; it shows that the adopters were older, had more years of experience in farming, less educated and had more adult members in the household compared to adopters. The adopters also had smaller farm sizes; were owners of the land they cultivated; had contact with agricultural extension service providers and belonged to farmers associations. There was no distinct difference between the two groups on access to credit facilities and male household heads. All adopters reported that the terraces were established on farm to retain water and allow slow percolation of water into the soil as a mechanism of coping with the changing rainfall pattern.

From the results the older and the less educated household heads adopted *fanya juu* terraces in maize and pigeon pea production compared to the young and more educated ones. This could be that most young household members were involved in non-farm income generating activities than the older ones. The less educated mainly depend on farming as livelihood and therefore keen to adopt technologies that have positive attributes like increase crop yield, reduce soil erosion while the more educated go to urban areas to seek for non-farm employment. These results contrast most adoption studies that a well educated household head has better perception of land degradation problems caused by climate change and are therefore more knowledgeable on SWC technologies to adopt (Pender and Kerr, 1998; Atampugre, 2014).

More years of farming increases the farmer's knowledge of rainfall patterns and the land degradation that results from changing climate and therefore increases their interest in SWC technologies. Households with more adult males adopted mainly because the labour required to make the structures is more masculine; which makes the male members take it up more easily compared to the females; an implication that most farming households depend on family labour. To circumvent the labour constraint farmers work in farmer groups.

More of the households with small land size parcels adopted fanya juu terraces than those with large farms this is attributed to the need to intensify agricultural production on smaller farms to increase productivity. This contrasts past studies that conclude that farmers with large landholding adopt terraces because of large space available to spare for the structural measures (Mengistu, 2009; Atampugre, 2014). Both owners and those just using the land either as care takers or lease adopted terraces in almost the same measure; this could be because most of the non-owner of land have access and utilize the land for more than one year. Most adopters had farms on a slope that necessitates some SWC measure to control massive soil erosion during the rain seasons. All the farmers interviewed had grown both maize and pigeon peas as they are the main staple crop.

Table 1: Descriptive statistics of Adopters and non-adopters of fanya juu terraces

	Machakos		Makindu		Mutomo	
H / H characteristics	**Adopt N=55**	**Non-adopt 45**	**Adopt 48**	**Non-adopt 52**	**Adopt 42**	**Non-adop 58**
Average Age (years)	62.8	44.38	61.6	43.3	59.6	46.7
Experience (years)	36.7	23.4	42.5	27.6	39.3	28.6
Male H/H head	68	70	74	76	80	60
Education (%)						
. No formal educ	6	4.9	8.3	10.2	8.1	13.5
. Adult educ	2	2.2	4.2	1	3.2	4.6
.incomplete primary	5	4.0	5.8	4.5	3.3	4.0
. complete Primary	42	39.0	20.0	19.0	30.0	32.0
.Incomplete sec. sch	14	11.5	10.2	8.5	8.4	9.8
. Secondary school	21	20.1	19.0	30.3	12.2	20.0
. Tertiary level	10	18.3	32.5	24.5	24.8	16.1
H / H composition						
Male >18years	2.3	1.6	2.5	1.2	3.8	2.3
Farm characteristics						
Farm size (acres)	2.23	2.6	4.22	6	4	4.3
Own land(%)	58	46.2	77	60.2	82.5	64.4
Access factor (%)						
Agric. Extension	74	55.9	83.3	53	84.1	47.1
Credit facilities	27	20.03	20.8	16.6	36.5	22.6
Climate information	75	8	72	15	56	12
Group membership	90	59.1	72.9	43.9	87.3	46.3

The results on access factor imply that agricultural extension service in Kenya is the main conduit of technology dissemination and capacity building of rural farming communities. Though the public agricultural extension staff is lean, they are able to visit farmer groups on demand and also provide weather advisory information in collaboration with Kenya Meteorological services. Both adopter and non adopters had not got any credit facilities to implement terracing on their farms even though the farmers were aware of availability of the credit facilities. They refrained from accessing them due to the stringent terms of accessing credit, high interest rates and the very short grace period on which they were required to pay back the debt.

Labour resource is a major constraint in adoption of fanya juu terraces, to establish the labour requirement the study investigated on the amount of man-days used to set up and maintain the structures on the farm. From the analysis, the average labour requirement for layout of terraces per hactare was 25 man-days, while labour required for excavating the structures was five times that of laying them out as shown in table 2. The labour requirement for establishing terraces was lower in Makindu and Mutomo relative to Machakos which could be attributed to the former having more stable soils and therefore easier to work on. The results are within the range of labour requirement of 186-281man days with 5-35percent slope in Central Kenya (Atampugre, 2014), in Usambara with slope of 5-55 percent had range of 143-222 man days (Tengberg et al., 1998

Annual maintenance cost of the terraces was KES 10,000 in Machakos and KES 10,670 in both Makindu and Mutomo. The cost accounts for about 17.8, 19.4 and 19.5 percent of total cost of establishing terraces in Machakos, Makindu and Mutomo respectively. The results are above the FAO recommended rate of 5- 10 percent (FAO, 2000). The results indicate that establishment and maintenance of terraces is a labour intensive practice. The laying out of terraces is highly manual; it entails aligning the terraces along the contour and marking the areas on which to establish the structures with pegs. The excavation of the terraces involves digging the trenches, leveling and compacting the embankment while establishing grass stabilizers requires planting the grass. The establishment of terraces is done before the onset of rains to avoid the predicament of unavailable labour once the rains set in; this is also used as a labour-cost reduction mechanism.

Planting grass stabilizers is done after the rains set in for maximum growth. The annual maintenance involves de-silting the trench and throwing silt up-slope, repairing any damages on the embankment or building them up annually, weeding the grass strip and re-gaping when necessary to keep them dense, trimming grass for fodder.

The results show a relatively high annual maintenance cost terraces which could be attributed to poor designing and layout of the structures. Most farmers design, layout and excavate the terraces in groups. The collective action enables the farmers establish terraces on their farms with some degree of ease. However, the poor layout and design is mainly due to inadequate technical skills. Though agricultural extension services are provided by the Government; the agricultural extension officers mandated to do the capacity building are often overwhelmed by the work because of the vast geographical area they cover and the limited facilitation in terms of transport and training materials to effectively carry out their task. This make capacity building of farm decision makers and those actively involved on the farms on construction of SWC structures necessary, and allocation of funds to enable the extension service providers reach the farmers is also necessary for efficiency and effectiveness in adoption of agricultural technologies.

Table 2: Cost of establishing fanya juu terraces and producing of maize and pigeon pea intercrop per hectare

	Machakos (KES)	**Makindu**	**Mutomo**
Lay out of terraces MD	5000(25)	5000(25)	5000(25)
Excavating terraces	36,400(182)	35,000(175)	34,000(170)
Establishing grass stabilizers	14,600(73)	15,000(75)	15,600(78)
Terraces maintenance	10,000(50)	10,670(53.35)	10,670(53.35)
Crop production input /year	60,000	57,550	58,300
Crop production labour/year	31,600(158)	27,800(139)	28,800 (144)
Total labour for establishment	280	275	273

Man days in paranthes; Labour in Man days. 1 MD= 6hours, 1 man day costs KES 200

The results in table 3 show that the gross margins of adopters of maize and pigeon pea production in *fanya juu* terraces in the entire study areas were positive indicating farmers gain by adopting the technology. Adopter got KES 70,391, 69, 616 and 65,305 per hectare per year in Machakos, Makindu and Mutomo respectively. The negative values are losses incurred for non-adopters. The gross margins were calculated for two rain seasons in one year.

Table 3: Gross margin analysis of maize and pigeon pea production in fanya juu terraces

		Terraces			**Without**	**Terraces**	
Description	Unit	**Total (KES)**			**Total (KES)**		
		Machakos	**Makindu**	**Mutomo**	**Machakos**	**Makindu**	**Mutomo**
Land preparation		12500	12000	12000	12500	12400	12400
Maize seed	Kg	7500	7500	7500	2840	3000	3000
Pigeon pea seed	Kg	7500	7500	7500	4250	3500	4500
Fertilizers	bags	8750	8250	8500	2500	2500	2400
Chemical	Litres	6000	6150	6600	3475	3475	3500
Planting	Mds	6000	5000	5600	5000	5000	5000
Weeding	Mds	13000	11000	11400	10000	10000	10000
spraying	Mds	1200	1200	1200	500	350	350
Crop harvesting	Mds	12000	12000	11000	2000	2000	1800
Threshing	Mds	6400	6000	6000	3600	4000	4000
Transporting		9000	8400	8700	5000	4500	5000
Grass harvesting		4400	4200	3900	0	0	0
Terrace maintenance	Mds	10000	10670	10670	0	0	0
Total cost		**104250**	**99870**	**100570**	**51665**	**50725**	**51950**
Maize		82096	82720	74000	26824	27250	30050
Pigeon pea		48285	44966	46675	21800	18900	17950
Crop residue		4260	3800	4200	1500	1950	1875
Grass		40000	38000	41000	0	0	0
Total Revenue		**174641**	**169486**	**165875**	**50124**	**48100**	**49875**
Gross margin $Ha^{-1} yr^{-1}$		**70391**	**69616**	**65305**	**-1541**	**-2625**	**2075**

The Gross margins for the adopters in the study area were high due to economic attributes associated with terraces that include increased crop yields, more income from the maize stovers, pigeon pea stalks and grass harvested on the terrace embankments that were sold as fodder to livestock producers especially to those rearing dairy cows and reduced damage that would have otherwise been caused by unabated soil erosion. The higher margins in Machakos relative to the other study area could be attributed to the lower transaction cost incurred marketing the farm produce. The gross margins underpin the importance of terraces and early maturing especially drought escaping varieties in adapting to climate change.

For benefit cost analysis, the cash flows of the adaptation option were discounted at 12 percent interest rate. The results in table 4 show that the adopters receive positive benefits on the third year of terraces establishment.

Table 4: Net present values of maize and pigeon pea in fanya juu terraces

Year	Present value	Machakos	Makindu	Mutomo
	0	-86,000	-84,330	-82,330
	1	-301	-6,450	-4,195
	2	48051	34,544	34569
	3	82349	58,726	47201
	4	86721	65,109	60845
	5	82,067	76030	70560
	6	75,935	62,305	65679
	7	69,568	56,045	60907
	8	58,749	44,591	55689
	9	54,363	41,396	49871
	10	46,859	37,560	43427
	11	40,545	34,370	39483
	12	37,533	31,361	36260
	13	33,863	28,436	33845
	14	30,644	26,919	29930
	15	27,515	24,345	27362
	NPV	688,461	530,956	569,103

The negative values in table 4 indicate the high initial investment cost and a decline in yield caused by reduction of the cultivable land on which the terraces are set and disturbance of soil during the excavation of the terraces. The early returns to the investment are attributed to sales of crop residues and the high yield. However, the results imply that farmers need more diversified crop and livestock production to cushion the farmers in the process of recovering the investment cost.

The results in table 5 reveal that the net present values of adoption of adopters in the entire study were greater than zero, the benefit cost ratios were greater than 1 and the internal rates of return were higher than the cost of borrowing capita which is an implication that the adaptation was profitable and therefore worthwhile for farming households to invest in. The results show that even when the cost of capital is altered by ± 2 percent to account for a future increase or decrease in cost of capital, the adoption of terraces would still be worthwhile as the benefits exceed the cost.

Table 5: Summary of Benefit cost analysis of fanya juu terraces

Benefit cost items	Machakos	Makindu	Mutomo
12% NPV(KES)	688,460	530,956	569,103
12% IRR	17%	14%	16%
12%B/C	1.53	1.41	1.46
10%NPV (KES)	794,037.3	617,877.8	660,621
10% IRR	19%	17%	18.5%
10%B/C	1.56	1.44	1.49
14% NPV(KES)	526,690	398,373.3	429,636.7
14% IRR	16%	14.8%	15%
14%B/C	1.50	1.38	1.42

Conclusion and Recommendations

Climate change poses challenges to agricultural production in Semi-arid areas of South Eastern Kenya. The predicted erratic rainfalls in terms of onset, cessation and intensity are likely to affect crop growth. Terraces have been promoted to retain excess water and allow slow infiltration of water in the soil for efficient crop use. However, the adoption of the technology depends on its efficiency in terms of outputs generated over the cost incurred.

The Benefit cost analyses results indicated that adoption of *fanya juu* terraces in semi-arid areas of South Eastern Kenya is profitable. The net present value of the benefits analyzed at 12 percent discount factor at the end of 15 years period was over KES 500,000; with benefit over cost (B/C) greater than 1 in the entire study area. Machakos had the highest benefits followed by Mutomo and then Makindu. The internal rates of return were all above the cost of borrowing capital. However, the study reveals a high annual terrace maintenance cost that was attributed to poor layout and excavation of the terraces.

The study recommends that policy intervention should improve farmers' access agricultural extension services to empower farmers in appropriate layout and designing of terraces that improves the efficiency of adaptation technology. Policies should also improve farmers access to credit facilities by improving the terms of lending money especially on the interest rates charged and the grace period required to pay back the loan to enable farmer acquire the required inputs for adaptation. High interest rate impedes most farmers access to the required farm inputs to enable them adapt to the changing climate while a shorter grace period before the farmers harvest their produce makes access to credit beyond their reach. Improvement of market environment is also required as an incentive to adopt the adaptation strategies whose yields have easy access to a functioning market to enable for the generation of maximum revenue, needed for the operation and maintenance of farm activities.

The study considered only one soil and water conservation technology, and recommends that future studies analyze the feasibility of more of these technologies to enable the choice of the most feasible technology in adaptation planning given the inherent budget constraints in the developing world.

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