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Land Use Activities and Their Effects on Soil Erosion on the Slopes of Kajulu Hills, Kisumu County, Kenya

Effectiveness of Mitigation Measures to Soil Erosion

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Abstract

Soil erosion is a natural phenomenon, but human activities accelerate it between ten to forty times the natural occurrences. It therefore calls for mitigating measure to curb the effects of erosion since soils form at a slower rate than they are destroyed. A study on land use activities and their effects on soil erosion was conducted in the upland ecosystem in Kenya, Kajulu hills. The study assessed the effectiveness of the mitigation measures adopted by the residents to ease the effects erosion on the hill slopes. A sample size of 295 households out of 1600 households engaged in various mitigating practices was used. The study collected data on the magnitude of soil (kg) lost from the arable lands using collector ditch technique. The data were analyzed using frequency distribution tables and Man U-test. The result showed a double amount (1.198kg/m^2) of soil lost on the arable land without mitigation measures as compared to plots under cut off ditches (0,615kg/m^2) and vegetative strips (0.904kg/m^2) with Man U=7. These findings were above the world wide estimation of soil erosion on arable mountainous regions which range between 1.3-40.kg/m^2/year (13-40T/Ha/year) as it was based on one rainy season.

Keywords: land use activity, mitigation measures, soil, soil erosion

1. Introduction

Soil erosion is one of the major environmental problems in the world. The soils form at slower rate than they are destroyed. Soil is formed at a rate of only 1cm every 200 to 1000 years on a parent rock under natural conditions (Ehrlich et al., 1997) and at least 200 years for a top soil under cultivation (Pimmental, 1993). It also takes 3000 to 12,000 years to build enough soil to form productive land. This means that soil is a non-renewable resource and once destroyed, it is gone forever hence the necessity to mitigate soils against erosion.

The problem of soil erosion and degradation in Sub-Sahara Africa is higher than in any other part of the world (Lal et al., 2001). Land use activities that have resulted to accelerated erosion are agricultural expansion into marginal lands, burning of pasture land, over grazing and de-vegetation (Huber et al., 1995; Kohler, 1987; World Resource Institute, 1990; Oldeman et al., 1990; Wageningen, 1990). It therefore requires actual conservation practices as well as formulation of policies in order to control the influence of the primary factors leading to soil erosion. This study focused on assessing the effectiveness of the mitigation measures adopted by the farmers living on the hill slopes of Kajulu to minimize the effects of soil erosion.

Controlling soil erosion requires data on relative erosion rates, spatial extents, vulnerable areas, current sources, relative contributions from different sources and likely effects on land use (Meijerink and Lieshout, 1996). In many areas, quantitative data on soil erosion rates is severely lacking (Nadeem, 1999). Thus, this study aims at filling this gap by proving data on erosion that is particular to the hills slopes of Kajulu since such data are very crucial in land management and decision making in assigning priorities for erosion control (Jack, 2002; Moore and Burch, 1986). This assists in designing suitable conservation measures (Kadupitiya, 2002a) to curb effects of soil erosion.

The temporal pattern of soil erosion is almost unknown and currently only sparse and rather anecdotal information exists (McClanahan and Obura, 1997; Cole, 2003). In Kenya, soil erosion was first reported in the mid 1930s but soil conservation measures begun in 1938 when a Commission on Soil Conservation (CSC) was formed (Tiffen *et al*., 1994). However, they added that, after 1963 when Kenya obtained her independence, the soil conservation measures were minimized or abandoned since it was believed to be associated with colonialism and was viewed as a form of punishment (Koning & Smaling, 2005). This was the period when the nature of approach to soil conservation changed from enforcement to advisory. This eventually led to a temporary breakdown of soil conservation activities*,* (UNEP, 1978) and accelerated erosion in post independent Kenya (Barber *et al*., 1979; National Research Council, 1993) and prompted the Government of Kenya to reinforce soil conservation activities by 1974 *(*Pretty *et-al*., 1995*).*

Erosion can be a severe problem in conventional farming especially on steep slopes (Hudson 1995; Nanna, 1996). Thus the need for pro-active steps to mitigate it effects. Worldwide conservation measures have employed contour principle techniques which are divided into engineering or mechanical and biological principles (Sanders, 1992). Engineering principles involve construction of barriers of various types, horizontally across the slopes either on or close to the contours of the land such as contour ploughing (Leroy, 1930), stone line/walls terracing and cut off ditches (Critchley *et al*., 1991).

The biological principle and practices include vegetative strips (Claudia *et al*., 2003), trash lines and planting of crops along the contours, a forestation and re forestation activities along the contours. This study used collector ditch technique to study soil erosion from arable plots under cut off ditches and vegetative strips on the hill slopes of Kajulu to assess their effectiveness. The collector ditch technique was a modification of the catch pit technique (Takei *et al*., 1981). The finding showed a double amount (1.198kg/m^2) of soil loss on the arable land without mitigation measures as compares to plots under cut off ditches (0,615kg/m^2) and vegetative strips (0.904kg/m^2) with Man U=7. These findings were above the world wide estimation of soil erosion on arable mountainous regions which ranges between 1.3-40.kg/m^2/year (13-40T/Ha/year) (Patric, 2002) as it was based on one rainy season.

2. Materials Studied

The study involved the mass of soil eroded from the arable plots and deposited into the collector ditches under plots having cut off ditches and vegetative strips as mitigation measures to erosion. The researcher also used questionnaires, interviews and observation as other main research tools to data collect data on the respondents opinions and attitudes towards mitigation measures to erosion on the hill slopes.

2.1 Description of the Study Area

The study was conducted on the hill slopes of Kajulu, Kajulu East Location, Kisumu County in Kenya. The area lies between latitude and longitudes are 0°57’05 South and 34°25’ East respectively and borders Nandi County to the East and Vihiga County to the West (www.getmap.net/maps/kenya/nyanza/kajulu.........29th December, 2019).

The area has a bi-modal type of rainfall falling between March to June and September to December with average annual rainfall ranges between 1200mm to 1300mm (Kenya Meteorological department, 2017). The soil type in the area ranges from sandy-loam along the rivers Kibos and Awach areas to sandy and weathered granites on the hills.

Most of the vegetation on the hill slopes are natural vegetation but have been de-vegetated due to land use activities such as need for wood fuel production, cultivation and grazing. These human activities have been associated with accelerated soil erosion in various parts of the world (World Resource Institute, 1990; Oldeman *et al*., 1990; Wageningen, 1990). The slopes have a filtration water intake which supplies about 1,700 metres cube per day, supplementing the Dunga water treatment plant which supplies about 18,700 metres cube per day from Lake Victoria and whose operations are often affected by the seasonal presence of water hyacinth in lake Victoria Winam Gulf (Lake Victoria South Waters Board (LVSWB), 2008). Hence the conservation of these slopes against erosion through proper mitigation measures is necessary in order to reducing polluting this important water source

3. Methodology

The research adopted a quasi-experimental research design employing empirical solutions model based on field observation of the visual indicators of erosion and collector ditch technique. It was concerned with assessing the effectiveness of the mitigation measures employed by the farmers to check the effects of erosion on the slopes. It particularly focused on two mitigation measures to erosion applied on the slopes namely cut off ditches and vegetative strips. These could be easily assessed using quasi-experimental research design.

Collector ditch technique is a modified simple catch pit technique which was first used in Java by Food and Agricultural Organization (FAO) in 1976 to study erosion on plots that lied along drainage lines or dry valleys (Takei., et al, 1981; FAO, 1976). However, in this study, catch pits were modified into collector ditches. The collector ditches were devised from the cut of drains dug in the farms to deviate excess water on the farm from causing erosion. The soils from the ditches were heaped on the lower side of the slope forming “Fanya chini” (heaping the earth on the lower side of the ditch) terraces which acted as erosion boundaries separating one plot from another. Thus, the catchment area for runoff causing erosion could be determined.

The bases of the catch ditches were covered with polythene roll so as to separate the deposited soil from the soil in the ditch and to facilitate easy handling of the deposited soil. Soil bulk density test was done for every site in order to determine the mass of soil loss in the area. Soil bulk density was found to be 1.7g/cm3 and 1.6g/cm3 in bush/forest lands and cultivated lands respectively. The mass of soil lost was obtained by multiplying soil bulk density by volume of soil deposited into the collector ditches.

4. Results and Discussion

Table 1. Perceptions on the effectiveness of the mitigation measures used to reduce the effects of erosion on the hill slopes of Kajulu (n=295)

Mitigation measure	Very effective		Effective		Not effective		Neutral		Slightly effective	
to check soil erosion	EPI	%	EPI	%	EPI	%	EPI	%	EPI	%
Contour ploughing	115	39	150	51	0	0	30	10	0	0
Trash lines	0	0	0	0	0	0	295	100	0	0
Agro-forestry	62	21	215	73	0	0	18	6	0	0
Fallowing	0	0	0	0	0	0	295	100	0	0
Cover cropping	62	21	233	79	0	0	0	0	0	0
Minimum tillage	0	0	0	0	0	0	295	100	0	0
Vegetative strips	65	22	212	72	0	0	18	6	0	0
Cut off ditches	68	23	215	73	0	0	11	4	0	0
Mulching	0	0	0	0	0	0	295	100	0	0
	352		1,025				1,157			

Source: Researcher, (2017).

Using the Likerts’ scale of 1-5 (Table 1). The summative effective perception index (EPI) varied from 233 as effective and 62 very effective on cover cropping while cut off ditches had 215 effective and 68 very effective in reducing the effects of soil erosion on the hill slopes of Kajulu, thus a positive perception. On adoption of agro-forestry, an EPI of 215 effective with a 62 EPI very effective while vegetative strips earned 212 effective and 65 very effective. Contour ploughing had an EPI of 150 effective and 119 very effective hence a positive perception. Despite the positive perceptions on the measures employed in the area to minimize the effects of soil erosion, it was observed that few people had embraced such conservation measures. Using the theory of planned behavior (Ajzen, 1991), a positive perception (attitude) depicted on table 1 among the respondents would result to a perceived social pressure to carry out such conservation measures that are perceived as effective leading to their successful application on the slopes of Kajulu.

Neutrally at 295 EPI on fallowing, minimum tillage, mulching and stone line conservation measures respectively, the local community was not sure on the effectiveness of the aforementioned conservation measures in checking erosion in the slopes of Kajulu. This was attributed to the fact that such conservation measures were not common in the area. From table 1, it was clear that no respondent perceived conservation measures as not effective or slightly effective. This shows that the locals were very much aware that any conservation measure to soil erosion would help minimize the effects of soil erosion. Hence, this study adopted a Man Whitney U-test to analyze the effectiveness of vegetative strips and cut off ditches on the slopes of Kajulu based on the section of the hill slopes.

Got Nyabondo area represented the upper slopes while Okok and Kadero areas represented middle section of the hill slopes of Kajulu. The two aforementioned conservation measures were chosen because of their effectiveness in soil erosion control on the slopes. They could be easily identified on the slopes of Kajulu as some cut off ditches and vegetative strips could be found on the non- arable parts of the slopes. The banks of the cut off ditches were planted with nappier grass for fodder thus forming vegetative strips thus the two conservation measures were used together. The study therefore adopted Man-U Test to analyze the effectiveness of the conservation measures (cut off ditches and vegetative strips) on the upper parts of the slopes (Got Nyabondo) and middles section (Okok and Kadero) sections of the slopes of Kajulu (Table 2).

Table 2. Man Whitney U-test statistics on cut off ditches and vegetative strips at Got Nyabondo (upper slopes) and Okok and Kadero (middle slopes) areas of the slopes of Kajulu (n=5)

		Total sample			
		Order from smallest to largest		Ranks	
Got Nyabondo	Okok / Kadero	Got Nyabondo	Okok / Kadero	Got Nyabondo	Okok / Kadero
1.2	1.82	0.35		2	
0.91	1.42	0.35	0.35	2	2
0.35	0.4		0.4		4
0.91	1.42	0.91		5.5	
0.35	0.35	0.91		**5.5**	
		1.2		7	
			1.42		8.5
			1.42		8.5
			1.82		10
				R1=22	R2=33

Source: Researcher, (2017).

Statistics for the Man Whitney U- test

U1= n1n2 + (n1(n1+1)) ÷ 2 –R1

U2=n1n2 + (n2(n2+1)) ÷ 2 –R2

Where:

R1=Sum of the ranks for the group1

R2= Sum of the ranks for group2.

U1=5(5) + (5(5+1) ÷ 2) – 22 = 18

U2=5(5) + (5(5+1) ÷ 2) – 33 = 7

U=7

Sum of ranks in (cut off ditches) R1 =22

Mean of ranks in (cut off ditches) R1=4.4

Sum of ranks in (vegetative strips) R2 = 33

Mean of ranks (vegetative strips) R2 = 6.6

R1 and R2 combined:

Sum of ranks = 22+33 =55

Mean of ranks = 55 ÷ 10 = 5.5

Median rank = 2, 2, 4, 5.5, **5.5**, 7, 8.5, 8.5, 10 = 5.5

Standard deviation = 4.787

From Table 2, it is evident that cut off ditches and vegetative strips were more significantly effective in soil erosion control at Got Nyabondo (upper slopes at rank 22) than at Okok and Kadero (middle slopes rank at 33). The null hypothesis being, upper slopes of Kajulu (Got Nyabondo) and middle slopes (Okok and Kadero) experienced equal amount of soil loss. A Man U-test value of 7 was calculated and it was above the mean and median values of 5.5 respectively and closure to the total of number of the observation made (10) (Table 2; Statistics for the Man Whitney U- test). It could be therefore deduced that cut off ditches and vegetative strips were more significantly effective at Got Nyabondo (upper slopes) than at Okok and Kadero (middle slopes). This significant difference in effectiveness of conservation measures used on the upper and middle parts of Kajulu slopes could be attributed to the slope gradient, distance between the cut off ditches and vegetative strips as well as the density of plants or crops cover on the field. The researcher was also interested to investigate on the respondents' perceptions on who has the responsibility to control the effects of erosion on the slopes. The findings are tabulated below.

Table 3. Whose responsibility to control soil erosion? (n=295)

Main responsibility	Frequency	Rank
The national government	211	4
County government	209	3
The local community	201	2
Every individual land user	280	1
Non-governmental organizations (NGO)	203	5

Researcher, (2017).

Table 3 explicitly reveals that most of the respondents (280, rank1) acknowledged that the main responsibility to prevent further soil erosion lies upon the individual land users or farmers themselves. This is because they are the first people to feel the effects of erosion such as decline in crop production and consequent famine among others. Local community was rank the second (Table 3**;** Rank 2) since the impacts of erosion affect them directly through decline in crop production leading to food shortage and also through increase in dependency ratio as those who would lack food will depend on others who have some little food.

The county government was ranked third (3) (Table 3). The argument was that environmental management and conservation is a devolved function under county government. National government and NGOs were ranked fourth (4) and fifth (5) respectively (Table 3). It was revealed that the national government played an important role in controlling erosion in the 1970s hence was believed to be able to do the same again. This response was common among the elderly people who have been living in the area from 1960s –'70s when soil conservation was a wide spread practice under the ministry of agriculture. The responses in Table 3 provide a clear indication that the locals were aware that they beared the first responsibility in environmental conservation yet it is their land use activities that have facilitated soil erosion on the slopes and were unwilling to work on voluntary basis to control the soil erosion problem in the area.

The study adopted Spearman's rank correlation to establish the nature of relationship between the local communities perceptions on who has the main responsibility to control soil erosion in the sub-locations lying on the upper slopes (God Nyabondo) and middle section of the hill slopes (Okok/Kadero) of Kajulu.

Table 4. A Spearman's rank correlation of the perception of the local communities of the Kajulu hill slopes on 'Whose responsibility to control soil erosion?'(n = 295)

	Got Nyabondo		Okok/Kadero			
Main responsibility	**values**	**Ranks**	**values**	**Ranks**	**d**	**d^2**
The National government	40	4	55	3	1	1
County government	60	3	45	4	-1	1
The local community	79	2	80	2	0	0
Every individual land user/farmer	95	1	99	1	0	0
Non Governmental Organizations	21	5	16	5	0	0
					$\Sigma d^2 = 2$	

Source: Researcher, (2017).

$$\text{Spearman's rank correlation (r)} = 1 - \frac{6\Sigma d}{n(n^2-1)}$$

$$r = 1 - \frac{6 \times 2}{5(5^2-1)}$$

$$r = 1 - \frac{12}{120}$$

$$r = 1 - \frac{1}{10}$$

$$r = 1 - 0.1$$

$$r = 0.9$$

Table 4, through calculations above shows that the Spearman's rank correlation (r) = 0.9. This value is closure to 1 and it signifies a strong/high positive correlation on the local communities' perception on whose responsibility to control soil erosion on the upper and middle sections of the hill slopes of Kajulu. It could therefore be concluded that there was a strong positive relationship between local communities perception on whose responsibility to control erosion in Got Nyabondo and Kadero/Okok sub-locations on the upper and middle sections of the hill slopes of Kajulu respectively.

5. Conclusion

In conclusion, there was a double amount (1.198kg/m^2) of soil lost on the arable land without mitigation measures as compares to plots under cut off ditches (0,615kg/m^2) and vegetative strips (0.904kg/m^2). The findings showed that the mitigation measures adopted by the farmers to check the effects of soil erosion were effective with Man U=7 under the cut off ditches and vegetative strips. However, the magnitude of soils lost from the arable plots were above the world wide estimation of soil erosion on arable upland ecosystem which ranges between 1.3-40.kg/m^2/year (13-40T/Ha/year) (Patric, 2002) as it was based on one rainy season.

6. Recommendations

The study recommends that advocacy and civil education on the need for mitigation measures to minimize the effects of erosion on the hill slopes of Kajulu should be improved. This should be done by the county government of Kisumu, the Ministry of Agriculture under national government through field extension officers, National Environmental Authority (NEMA), and elected leaders who have immense influence over the electorates. This should be followed by moral, material and financial subsidy to achieve this goal.

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