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

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Abstract:
Human activities have globally accelerated soil erosion between ten to forty times the natural occurrences. A study on land use activities and their effects on soil erosion was conducted in the upland ecosystem in Kenya, Kajulu hills. The study determined the relationship between land use activities and soil erosion to see the effects of land use activities on the magnitude of soil erosion. A sample size of 295 households out of 1600 households engaged in various de-vegetative practices was used. The study collected data on the depth of erosion (mm) using erosion pin technique. The resultant data were analyzed using measures of central tendency and correlation analysis. The finding showed no observable change on the heights of erosion pins on the vegetated parts of the slopes whereas the de-vegetated parts of the hill slopes had an erosion depth of between 8mm and 7mm which were equivalent to 80m^3/Ha. and 70m^3/Ha. or 1.36kg/m^2 and 1.19kg/m^2. These findings were above the world wide estimation of soil erosion on mountainous regions with normal vegetation which ranges between 0.1-0.5kg/m^2/year (1-5T/Ha/year) as it was based on one rainy season. Thus, the need to re-vegetate the de-vegetated hill slopes in order to control soil erosion and curb its adverse effects.

Keywords: *Soil, soil erosion, Levels of soil erosion, Land use activities*

1. Introduction

Soil erosion is the most serious form of land degradation (Nanna, 1996; Sohan and Lal, 2001). Soils form at a very slow rate than they are destroyed. It takes between 200 to 1,000 years for a top soil under cultivation to form 1centimetre of soil (Pimmental, 1993) and 1000 years for a parent rock under natural conditions (Ehrlich et al., 1997). This calls for the need to conserve soils. On the hill slopes of Kajulu, soil erosion is a reality as evident by presence of gullies, rills, exposed rocks and plant roots, rock pedestals and bare surfaces. This has led to reduction in agricultural land as well as reduced agricultural production. Hence the fear that if the present soils are not conserved and further erosion checked, then there would be no fertile soil in future to sustain agricultural production leading to food shortage and consequently famine, starvation and malnutrition related diseases and death.

Land use activities such as agricultural expansion into marginal lands, burning of pasture land and de-vegetation have led to accelerated and spatial increase in erosion (Huber et al., 1995, Kohler, 1987). In North America, agricultural practices formed the highest percent (66%) of anthropogenic erosion. In Asia, Africa and Oceania, overgrazing contributed the highest percentage (80%, 49% and 35% respectively) of anthropogenic erosion. In Europe, de-vegetation contributes to the highest contributor to anthropogenic erosion standing at 38% (World Resource Institute, 1990; Oldeman et al., 1990; Wageningen, 1990). This study focused on de-vegetation and its effects on soil erosion on the hill slopes of Kajulu, Kisumu County, Kenya. It compared the extent of the variations of soil erosion on the de-vegetated and vegetated parts of the slopes based on the visual indicators of soil erosion. Other studies on soil erosion have used visual indicators to study soil erosion such as presence of rills, gullies, rock pedestals, bare surfaces, exposed plant roots and rocks among others (Takei et- al., 1981).

De-vegetation removes of all kinds of vegetative cover on the earth's surface through logging, overgrazing or general clearance of land for cultivation. Clearance of vegetation destroys the buffer between the soil and the atmosphere hence the rainfall intensity and duration have immense impact on the soil causing erosion (Hagos, 1958; Morin 1963). Plant roots hold the soil mechanically and increase the surface roughness and reduce the speed of runoff (Morin, 1963). Vegetation through the action of their fallen and decomposed leaves aid in the formation of organic matter to form humus which improves the soil structure by cementing the soil pores. The accumulated leaves on the soil intercepts the direct rain drops or the secondary rain drops after initial interception by the canopy thus increasing the rate of water infiltration into the soil. Absence of vegetation cover thus increases soil erosion.

In Missouri, barren land lost soil at a rate of 123 times that of land that was covered with vegetation (Pimental et al., 1999). Similarly, in Oklahoma, areas without rye grass or wheat cover lost 2.5 to 4.8 times as much soil as land with cover (Pimental et al., 1999). On the hill slopes of Kajulu, de-vegetated parts of the hill slopes lost soil 7 to 8 times the vegetated parts (7mm-8mm depth) based on erosion pins.

De-vegetation is caused by high demand for wood fuel and land for crop cultivation resulting to clearance of vegetation (Abebe and Endalkachew, (2001). It is estimated that about a quarter of the world's forests have been harvested for fuel and converted into charcoal for domestic and industrial purposes (FAO, 1987). The vegetation has been transformed and soils losing its fertility mostly due to human activities (Bainbridge, 2007). Areas which were once highly forested have been reduced to dry or desert lands while desert like conditions keep on encroaching into vegetation zones (Bainbridge, 2007; Arnalds et al., 2001). With the absence of plant cover, erosion occurs and sweeps away the top soil (Hagos, 1998).

The hill slopes of Kajulu have been bare and de-vegetated, nevertheless, efforts have been made by Lake Basin Development Authority (LBDA) in 2010 and Lake Victoria Environment Management Program phase II (LVEMP II) 2014/2015 planted seedlings on the steeper parts of the slopes but these steps have not fully addressed the erosion problem since most of the planted seedling died or interfered with by human activities leading to accelerated erosion on the hill slopes. Thus, this study sought to compare the level of soil lost from the slopes based on erosion pin technique {(Haigh (1997); Lawler (1993); Higuchi et al., (2013); Hancock and Lowry (2015); Boardman et al., (2015) and Evans (2015)}.

2.1. The Study Area

The study was conducted on the hill slopes of Kajulu, Kajulu East Location, in Kisumu East Sub-County, Kisumu County in Kenya. The study area falls in three sub locations namely: Okok, Got Nyabondo and Kadero. 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 hill slopes of Kajulu are at elevation of 1400m above sea level (Map of Kisumu East, sheet map No.116/2, map seriesY731 D.O.S 423). It experiences modified equatorial climate with the modification due to the presence of Lake Victoria and high altitude (Pidwirny and Jones, 2009). 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 often affected by the seasonal presence of water hyacinth in Lake Victoria Winam Gulf (Lake Victoria South Waters Board (LVSWB), 2008).

2.2. Material and Methods

This study was conducted through a quasi-experimental research design employing empirical solutions model based on field observations and erosion pin technique. It was concerned with comparing the variations of the extent of soil erosion among the de-vegetated and vegetated parts of the hill slopes of Kajulu. It particularly assessed the relationship between land use activities and soil erosion on the hill slopes. This could be easily assessed using quasi-experimental research design. The design enabled the researcher to acquire information through observation of the visual indicators of erosion which were naturally available for study and also estimate the amount of soil lost from the slopes through measurement of the erosion pin depths (Takei et al., 1981; Haigh (1997); Lawler (1993); Higuchi et al., (2013); Hancock and Lowry (2015); Boardman et al., (2015) and Evans (2015)}.

The researcher used questionnaires, interviews, taking of measurement of depth of rills and gullies and observation as the main research tools for data collection. The erosion pin technique was conducted by driving pins into the soil base level such that erosion on the site was indicated by the height of the pin exposed to the soil surface (Takei et al., 1981). The pins were made up of iron nails of length ranging from 20-50cm depending on the depth of the soil and a diameter of 5-10mm. This thickness was preferred to avoid interfering with the surface flow and also cause scouring of the base when thicker pins are used. Readings on the changes of the heights of erosion pins were taken using a hand tape measure three times during the study period. The pins were enamel painted to improve on their visibility and were installed at 5m interval square grid on three 100m2 plots. Other studies have used varied number of pins to represent erosion. For example: Higuchi et al. (2013) used 10 pins, Evans (1977) used 301 pins and Boardman et al. (2015) used 250 pins to represent erosion in Badland area USA. The depth of soil loss on the slopes was determined by finding the mean height of erosion on the sites which were 8mm and 7mm on the middle and upper section of the hill slopes respectively.

The researcher was also concerned with opinions and views of the respondents. Such information could be best collected using the given research tools (Cauvery et al., 2007; Oso and Onen, 2005). Percentage distribution technique was used to show the frequency of the respondents' views on de-vegetation and soil erosion on the slopes. Chi-Square test for goodness-of-fit was used to analyze the frequencies in line with the research questions (Kothari, 2004; Oso and Onen, 2005). Conversely Likert scale for opinion was used where respondents were required to give their opinions on historical view of vegetative land cover as was expressed on the questionnaire. The study also used Pearson's Product Moment correlation (r) to analyze the relationship of soil erosion between the upper and middle sections of the slopes based on the results from the erosion pins. The result showed a weak positive correlation with r=0.643

3. Results and Discussion

Table 1: Chi-square characteristics value on the respondents' perceptions on land use activities and de-vegetation on the hill slopes of Kajulu

Land Use Activity Categories	Observed	Expected	(O-E)	(O-E)²	$\frac{(O-E)2}{\sum}$	Critical value
Wood fuel (firewood and charcoal)	80	295	-215	46,225	0.162	9.210
Cultivation practices	103	295	-192	36,864	0.129	9.210
Grazing	56	295	-239	57,121	0.200	9.210
Sand harvesting/quarrying	56	295	-239	57,121	0.200	9.210
Shifting cultivation	0	295	-295	87,025	0.306	9.210
Σ	295	295		284356		0.997

Table 1

Therefore Chi- square = (O-E)2/(∑)
Df = 2 at 0.01 = 9.210; X2 = 0.997. Source: Researcher, (2017)

Chi square characteristics (Table 1) clearly reveal that there was a significant relationship between land use activities and de-vegetation on the hill slopes of Kajulu. The table reveals that wood fuel harvesting was statistically significant to de-vegetation at (0.161<9.210 df = 2 at 0.01). The term wood fuel as is used here refers to charcoal and firewood. Cultivation practices were perceived to significantly affect de-vegetation and subsequent erosion at (0.129<9.210 df = 2 at 0.01).

Besides cultivation practices, grazing, sand harvesting and quarrying activities were equally statistically significant at (0.200<9.210 df = 2 at 0.01) (Table 1), however, empirical studies revealed that grazing was not a major economic activity in the area (at 19%, Table 1) since majority of the residents were arable farmers. Those who had livestock hardly have more than four heads of cattle. Nevertheless, grazing was quite practiced at some parts of Got Nyabondo sub-location bordering Okok and Kadero sub-locations. According to oral interview sources, these were the areas where LVBDA and LVEMP II unsuccessfully tried to reforest from the year 2013. Despite the 'failure' in reforesting the bare parts of the slopes, some pockets of forest could be observed on the slopes courtesy of LVEMP II 2015. Shifting cultivation was not practiced in the area (Table 4.14) due to scarcity of land, however, it was statistically significant to de-vegetation at (0.306 < 9.21 df = 2 at 0.01).
The understanding of the respondents' perception on de-vegetation is tabled below.

Type of Vegetation	Very Much		Much		Few	
	%	f	f	%	f	%
Grass	65	22	139	47	91	31
Shrub	115	39	129	44	51	18
Trees (forest)	32	11	69	23	194	66
Mixture of trees and shrubs	56	19	109	37	129	44
Mixture of trees, shrubs and grass	53	18	62	21	180	61

Table 2: Type of Vegetation Common on the Hill Slopes of Kajulu (N=295)
Source: Researcher, (2017)

Table 2 has it that shrub was the most dominant vegetation on the slopes of Kajulu at 39% (very much) and 44% (much) of the respondent's views. It was revealed that tall trees had been cut down for timber and wood fuel thus few on the slopes at 66% (Table 2). This paved way for the growth of shrubs and grass at 22% and 47% dominance. Observation had it that grass and scattered shrubs were common in some parts of God Nyabondo where grazing was the dominant land use activity. Table 2 reveals presence of few (44% and 61%) mixture of trees and shrubs and mixed stands of trees, shrubs and grass on the hill slopes of Kajulu respectively. However, it was observed that these vegetation types were only peculiar to Got Nyabondo area on the sides neighbouring Kajulu water filtration intake which were unsettled but was facing encroachment from settlers and farmers.

Figure 1: Shrub Vegetation on the Fallowed Parts of the Hill Slopes of Kajulu
Source: Researcher, 2017

Figure 1 supports the assertions made by the respondents that shrub was the dominant vegetation type on the hill slopes of Kajulu. The figure clearly shows that fallowed and marginal lands on the slopes have been encroached and cultivation carried out without proper mitigation measures. Since the fallowed bushy area facing encroachment by farmers is adjacent to the Kisumu water filtration intake at Kindu in Kadero/Got Nyabondo area, the water filtration plant risks siltation by soil from the adjacent farms.

In order to get historical information about vegetative soil cover and agricultural arable land, the respondents were asked to give their views on the vegetative land cover and agricultural arable land in as long as they could remember. The respondents interviewed were 30 years of age and above. This age bracket was chosen because they had stayed in the area long enough to witness the changes in the vegetative land cover in the area. The resultant data is shown in Table 3.

Factor	%	Attitude index	Factor	%	Attitude index
Vegetation			Vegetation		
Grass			Bare land		
Much increased	0	0	Much increased	50.2	148
Increased	0	0	Increased	40	11
Same	0	0	Same	0	0
Decreased	30.16	89	Decreased	0	0
Much decreased	69.84	206	Much decreased	0	0
Don't know	0	0	Don't know	9.8	29
Bush			Agriculture		
Much increased	0	0	Food production		
Increased	0	0	Much increased	0	0
Same	0	0	Increased	0	0
Decreased	40	118	Same	0	0
Much decreased	60	117	Decreased	40	118
Don't know	0	0	Much decreased	29.83	88
Trees			Don't know	29.83	88
Much increased	0	0	Cultivatable land		
Increased	8	24	Much increased	20	59
Same	0	0	Increased	70	206
Decreased	20	59	Same	0	0
Much decreased	50.2	148	Decreased	70.8	206
Don't know	21.8	64	Much decreased	20	59
			Don't know	10.2	30

Table 3: Opinions of the Local Community's Living on the Hill Slopes of Kajulu on the Historical View of Vegetative Land Cover on the Hill Slopes of Kajulu (N=295)
Source: Researcher, (2017)

Using the Likert's scale rate of 1-6 (Table 3), the summative opinion index on grass varied from 206 as much decreased to 89 decreased vegetative cover on the slopes of Kajulu. The Table 3 succinctly shows that bush (shrub) vegetation cover on the hill slopes of Kajulu have much decreased and decreased with an opinion index of 177 and 118 respectively. The opinion of the local community on the historical tree cover varied from 148 much decreased, 64 neutral and 59 decreased. Conversely bare land had an attitude index of 148 much increased and 29 neutral (Table 3). From table

4.16, it could be deduced that vegetation cover on the hill slopes of Kajulu has been reducing in time thus concurs with the findings made by Bainbridge, (2007) and Arnalds et al., (2001) who assert that vegetation worldwide has been transformed due to human activities and forested regions have been reduced to dry or deserts lands}. Erosion pin technique was used to approximate and compare the rate of soil loss in vegetated and de-vegetated parts of the hill slopes of Kajulu under various land use covers. The findings are shown Table 4.

Land Use Activity	**Size (M2)**	**Mean Erosion Depths (mm)**	
		Got Nyabondo	Okok and Kadero
Natural vegetation (bush) (NV)	100 x100	No o change	No observable change
Mixed forest NVPT (MF)	100x100	No change	No observable change
De-vegetated and bare land (DB)	100x100	7	8

Table 4: Data from Erosion Pin Technique on the Hill Slopes of Kajulu
Source: Researcher, (2017)

From Table 4, Got Nyabondo area represented the upper parts of the hill slopes while Kadero and Okok areas represented the middle section of the hill slopes. Table 4 shows that the upper parts of the slopes had a mean erosion depth of 7mm while the middle section of the hill slopes had a mean erosion depth of 8mm on de-vegetated areas. It is explicitly clear that there was no observable change realized on the depth of erosion pins on vegetated areas. This was attributed to the influence of vegetation over and on the soil over the short period of the study. The vegetative canopy over the soil intercepted the rain drops and reduced their intensity resulting to minimal impact on the soil to cause erosion. The roots of plants on the other hand checked the speed of runoff thus reducing erosion. Similar findings had been made by (Mkhonta, 2000; Petter, 1992; Hagos, 1958; Morin, 1963). Secondly, the hand tape measure used to measure erosion depth could not measure less than 1mm.

Table 4 has it that the middle section of the slopes recorded higher erosion depths than the upper section due to accumulation and increase of velocity of runoff from the upper slopes. Takei et., al 1981 found an erosion depth of 13mm/Ha/year on a study of soil erosion on a newly cleared forest in Japan with annual rainfall of about 1530mm. Kajulu hill slopes, lying in the Lake Victoria region with an annual rainfall of approximately 1200mm with a double maxima rainfall regime producing 8mm a season is a good measure of comparison. The erosion depths were mainly attributed to three rain storms that occurred during the study period.

From Table 4, corresponding volumes of soil lost from the erosion depths were estimated by multiplying the mean erosion depth and the surface area of erosion as shown.

Middle section of the slopes -Kadero/ Okok
Volume (V) = Surface area (S.A) x Height (h)
=100m2 x 8mm
=100,000,000cm2 x 0.8cm
=80, 0000, 000cm3
=80m3/Ha

Thus, the middle section of the slopes (Kadero/ Okok areas) with an erosion depth of 8mm corresponded to a volume of 80m3/Ha. The upper section of the slope (Got Nyabondo region) with erosion depths of 7mm corresponded to a volume of 70m3/Ha as shown below.

Volume (V) = Surface area (S.A) x Height (h)
=100m2 x 7mm
=100, 000, 000cm2 x 0.7cm
=70,000, 000cm3 x 0.7cm
=70m3/Ha

Erosion pin technique was also employed to study the rate of soil loss from the middle section of the slopes (Okok and Kadero) and the upper (Got Nyabondo) parts of the slopes of Kajulu. The resultant data is shown in Table 5 below.

Heights of Erosion Pins (mm)						**Mean height (mm)**	
Middle Slopes	8	7	9	8	7	7.8	-8
Upper Slopes	7	6	7	8	6	6.8	-7

Table 5: Mean Heights of Erosion Pin Technique on the Hill Slopes of Kajulu (N=5)
Source: Researcher, (2017)

The Table 5 clearly shows that the mean heights were rounded off to the nearest 10 since the hand tape measure used could not measure decimal figures. The data (Table 5) was analyzed using Pearson's product moment correlation coefficient to compare the degree of erosion between the upper slopes and middle slopes sections of the Kajulu hills as indicated in Table 6.

		X	Y	XY	X2	Y2
		8	7	56	64	49
		7	6	42	49	36
		9	7	63	81	49
		8	8	64	64	64
		7	6	42	49	36
	Σ	39	34	267	307	234
Mean		7.8	6.8	53.4	61.4	46.8

Table 6: Correlation Coefficient Characteristics of Erosion between the Middle Slopes (X) (Okok and Kadero) and Upper Slopes (Got Nyabondo) (Y) Sub-Locations of the Hill Slopes of Kajulu
Source: Researcher, (2017)

From the Table 6, Pearson's product moment correlation was obtained as follows:
Product moment correlation coefficient (r) = change in xy ÷ change in x by change in y
r = Dxy/DxDy……………………………. (i)
Change in xy (Dxy)
Dxy = Exy/n –Mean (xy)……………(ii)
= 267/5 - (7.8 X 6.8)
= 53.4 – 53.04
= 0.36
Change in x2 (Dx2)
Dx2 = Ex2/n – Mean of (x2)
= 307/5 – 7.82
=61.4 – 60.84
= 0.56
Therefore, change in x
(Dx) = $\sqrt{0.56}$
= 0.748
Change in y2 (Dy2)
Dy2 = Ey2/n – Mean of (y2)
= 234/5 - 6.82
= 46.8 – 46.24 = 0.56
Therefore, change in y
Dy = $\sqrt{0.56}$ = 0.748
The r value now is r =Dxy/DxDy
= 0.36/(0.748 X 0.748)
= 0.36/0.56= 0.643
Coefficient determination of r is given by (r2);
r = 0.643
r2 = (0.643)2
r2 = 0.413

From the calculations above, there was a significant positive correlation between soil erosion on the upper slopes and middle slopes sections of the hill slopes of Kajulu. The correlation (r) value of 0.643 and coefficient (r2) value of 0.413 indicate a positive correlation though not very strong. This is also revealed in Table 5 where the differences in the mean height of the erosion pins from both sections of the hill slopes were small with a difference of 1mm. From the correlation, it can be deduced that there was a 41% chance that erosion on the upper slopes of the hills will result to an increase in erosion on the middle section of the slope. This could result to the 1mm variation in the erosion pin depths on the two sections of the slopes.

Available literature reveals that studies on soil erosion using erosion pin technology have produced different results based on changes on the heights of erosion pins. {Takei et al., (1981) found an erosion rate of 13mm/year on slopes recently cleared of forest in Japan while Hudley and Lusby (1967) found an erosion rate of 2.7mm based on one high rain storm of 28mm in 6 hours and 30 minutes on hill slopes of Mances Shales small catchment. Other studies that have also used erosion pin technique include Haigh (1997); Lawler (1993); Higuchi et al., (2013); Hancock and Lowry (2015); Boardman et al., (2015) and Evans (2015)}. This study having an erosion rate of 7mm and 8mm on a single maxima rainfall regime was a good measure of comparison.

4. Conclusion

In conclusion, there was no observable change on the heights of erosion pins on the vegetated areas depicting minimal erosion while in the de-vegetated parts of the hill slops, changes on the depth of erosion pins varied from 7mm on the upper slopes to 8mm on the middle slope sections. This was equivalent to a soil loss of 70m3/Ha and 80m3/Ha for the three months the study period.

5. Recommendations

The researcher recommends the following based on the study findings. The county government of Kisumu should enforce environmental policies regarding the root causes of de-vegetation in the area such as haphazard sand harvesting, cutting down of vegetation for wood fuel purposes and farming on the hill slopes without proper mitigation measures. The local farmers should be encouraged to practice agro-forestry by providing them with seedlings. Local politicians in the area should educate the area residents on the importance of vegetation cover since they have influence over the voters and also fund a forestation programs through National Government Constituency Development Fund (NG-CDF).

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