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Sand Extraction and Land Degradation in Nyakach Sub County, Kisumu County, Kenya

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Abstract:

Invariably degrading land in Nyakach Sub County despite conservation efforts can be attributed to endemic indiscriminate sand harvesting. In seeking a lasting solution this study employed mixed method (Creswell J. W., 2006) bringing together cross sectional study design employing field based observations and quasi experimental design employing stream sand budget analysis. The former enabled the researcher to collect both quantitative and qualitative data on quantities of sand extracted and extraction frequencies at particular points in time while the latter enabled empirical experiment to evaluate stream sand budget analysis. Using Sloven's formula $n = N / (1 + Ne^2)$ with a confidence level of 95% giving a 0.05 margin of error, the sample size of 398 respondents, at 75% rate of return, 298 respondents were used. Employing questionnaires, observation and interviews to collect and analyzing the resultant data using Pmcc, the resultant r value of 0.95 and a coefficient r^2 value of 0.90 revealed a very strong relationship between sand extractions and Land degradation. Sand winning was responsible for over 50% of land degradation directly and indirectly. On of reference state and stream sand budget, the study recommended technically informed and sustainable sand exploitation alongside physical structures, terraces alongside reseeding for severely degraded land as suggested by (Oldeman et al. 1990).

Keywords: Sand budget analysis, reference state, land degradation, artisanal mining

1. Introduction

Sand extraction entail all activities that draw solid crustal material of grain diameters ranging between 0.002 to 0.08 inches for economic or any other uses. Such solid materials exist on the surface of the earth unconsolidated or embedded between layers of crustal materials (Hull, 2001). Sand harvesting is one of the largely unregulated artisanal mining activities involving scooping and moving large quantities of solid material from one part of the earth to another modifying sizeable section of the earth positively but to a large extent negatively (Hooke, 2000). Done without due consideration of its potentially adverse effects on land such activities while profitable, exert unmatched strain on land and its inherent resources posing great danger to current and future biodiversity. Assessments of the percentage of ice-free land affected by human action show variations from 20% to 100%. Humans appropriate 20% to 40% of earth's potential net primary biological production (Haberl et al., 2007; Imhoff et al., 2004; Vitousek et al., 1986).

Nearly 24% of Earth's surface area had experienced decline in ecosystem function and productivity between 1981 and 2003 (Bai et al., 2008). As of 1995, ~43% of Earth's surface area had experienced human-induced degradation (Daily, 1995). A study by Ellis and Ramankutty (2008) concluded that more than 75% of Earth's ice-free land area could no longer be considered wild. Of the earth's ice-free land area, approximately 83% is likely directly influenced by human beings through lithospheric exploitations including the prevalent sand winning (Sanderson et al., 2002).

Globally, Asia is the largest and most populated continent in the world, sitting on a total land area of 4.3 billion hectares. Some of the degraded areas on the Asian continent include expanding deserts in mainland China, India, Iran, Mongolia, and Pakistan, the sand dunes of Central Asia which have attracted large scale sand winning, the steeply eroded mountain slopes of Nepal, and the deforested and overgrazed highlands of the Lao People's Democratic Republic Delahunt (Olschewski, R., Kleinn, C., & Gebrehiwot, K. (2007). Similarly, Lower Nyakach sits on large quantities of deposited sand periodically replenished by scarp slope erosion from the Nyabondo plateau scarps (Saggerson, 1947). This phenomenon has attracted artisanal sand mining activities with a host of small-scales and winners in the region indiscriminately harvesting sand regardless of the associated degrading effects. Makweba, M. M., & Holm, E. (1993) concur that sand represents the main source of construction material used throughout the world, with countries like India being among leading consumers of sand. However, indiscriminate sand winning done without proper sediment budget analysis and inadequate mitigation, he observes, has led to severe degradation of land (Makweba, M. M., & Holm, E. 1993).

Sand extraction in Ghana largely draws sand from natural deposits where the grains of sand occur naturally at the sea coast, riverine and savanna areas. In addition to the sand and gravel, granules and pebbles of gravel are derived from the earth or crushed from quarrying rock (Peprah, K., 2013). In the Northern region of Ghana and the East Gonja District (EGD) Sand mining has been one of the activities posing the most serious environmental problems wherever it is done often resulting into, loss of agricultural lands and biodiversity as well as increased poverty among people (Musah, 2009). Sand is among the primary raw materials for the construction of factories, roads and bridges, houses, and other infrastructure in the built environment. The higher demand for this basic building resource in Nyakach and regions surrounding it has resulted in land degradation in the region due to heightened excavation of the sand to meet the demand. Degradation is evident in loss of arable land, loss of biodiversity, proliferation of badlands, decline in crop production, aggravated soil erosion and vegetation cover reduction, hence the rudimentary efforts of the farmers and NUSA.

Nyakach Sub-county falls within severely anthropogenic degraded regions due to sand harvesting alongside other forms of lithospheric exploitations (FAO/AGL 2005). This observation is corroborated by the actual situation on the ground taking into consideration the main economic activity after farming in Nyakach. Sand extraction in Lower Nyakach is directly linked to the severity of the degradation owing to a strong relationship, $r = 0.952$ (pmcc) between extraction and land degradation. Mitigation measures for degraded land in Nyakach therefore require physical structures, terraces alongside reseeding to permanently forestall the adverse effects of this seemingly profitable economic activity (Oldeman *et al.* 1990). Generally, land degradation levels vary considerably over regions from 27% in Africa, 35% in Kenya, and up to 50% in Nyakach Sub-County and this is largely due to varied human activities that have directly degraded land or indirectly by exposing land to degrading agents such as water erosion as was observed in previous studies (Kodiwo and Ang'awa 2012).

2. Methods

The study employed mixed method (Creswell J. W., 2006) bringing together cross sectional study design employing field based observations and quasi experimental design employing stream sand budget analysis. Cross sectional research design enabled the researcher to collect both quantitative and qualitative data at particular points in time on quantities of sand extracted and extraction sites while quasi experimental design enabled the researcher to carry out empirical analysis of stream sand budget and dynamics against extraction.

A stratified sampling technique interestingly found relevance in this study in that the target population was by virtue of the location of sand mines stratified and the respondents recruited subsequent respondents making snowball sampling technique a necessity. Employing Sloven's formula $n = N / (1 + Ne^2)$, with a confidence level of 95% giving a 0.05 margin of error, the sample was $n = 150,915 / (1 + 150,915 * 0.05^2)$ this gave a sample size of 398 respondents, at a 75% rate of return 298 responses were analysed.

3. Types of Data and Collection Methods

Both qualitative and quantitative data were collected from both primary and secondary sources through; direct observation, interviews, administering questionnaires and focused group discussions. Primary data constituted; quantities of sand in trucks, sand pit depths, sand deposit depths in feet, areas of arable land lost and the encroachment distances. The county revenue office provided primary data on quantities of sand that pass through their office in terms of number of trucks and frequency to determine the relationship between quantities of sand harvested and the rate of land degradation.

The researcher employed the Google earth pro app, a computer software to take an aerial tour of Nyakach observing finer details of inaccessible areas. The Google earth pro app ruler of the 2018 CNES/Airbus of the Maxar technologies accurately measured distances and dimensions such as gully widths, shift distances of shifting rural access roads, sand pit and quarry dimensions. Such measurements were complemented by on-ground direct measurements.

4. Sediment Budget Analysis

Sediment/Sand budget is a mass equilibrium or difference between sediment in-put and out-put in a stream channel resulting from the cycle of erosion, transportation and deposition of sediments. In such measurements, field and air photo observations are used to estimate the annual amount of sediment eroded and deposited within a sub watershed, the net difference (input – output) should equal the amount of sediment passing a gauge at the mouth of the watershed (Foltz, Randy B.; Burroughs, Edward R., Jr. 1990). Sand budget analysis has been used in Idaho to predict down slope travel of granitic sediments from forest roads and to examine the effects of logging roads on sediment production rates in the Idaho batholith (Megahan, W.F.; Ketcheson, G.L. 1996).

The researcher modified sand budget analysis considering stream sand input and output by harvesters to gauge the role of stream sand harvesting on stream channel degradation. The modification here was informed by the fact that there are no sediment budget models involving humans directly as geomorphic agents. SAWT, USLE or a modified version such as MUSLE models have been used to estimate sediment yield from a watershed and to analyze impacts of change in land use and sediment generation (Schmidt *et al.*, 2008). However, this study considered empirical measurement inputs and outputs with regards to anthropogenic influence.

Depths of sediment deposits were measured before and after deposition at randomly sampled sand harvesting sites within Omondo, Katuk Odeyo, Jimo Olwalo, Asawo, and Bugo all of which were representative of Lower Nyakach region. Initially sand free harvesting spots on channel floors were identified before the onset of the long rains between March and July 2018 whose overland flows deposit sand in the streams. The depths of sand deposits were measured on

nine calibrated metal rods dug deep in to the ground at the sampled sand harvesting sites sunk deep at the middle of the harvesting sites and on the downstream end of the harvesting sites. The readings were then averaged to come up with the general deposit depth.

Reference state is the state of basic biodiversity in relation to ecosystems in a stream channel. It is an important determinant of the quantity and technology in exploiting lithospheric resources. Besides, it also determines the need and method of mitigation (Goddard, 2007). Alteration in the reference state of a stream is one of the indicators of stream channel degradation. The drainage channels of Nyakach. Omondo, Katuk Odeyo, Ragen, Bugo and Olwalo channels were sampled as representative of the entire Sub County and the state of biodiversity interrogated for the past ten years.

5. Results and Discussion

Administration of questionnaires yielded 298 respondents being 75% rate of return. All the 298 respondents were drawn from the local community in the five wards of Nyakach sub-county, namely, South West, South East, West, Central and North Nyakach. About 10% of the respondents were below 18 years, minors (Constitution of Kenya, 2010) pointing to the fact that sand winning attracts a host of harvesters regardless of age hence greater degradation. Central Nyakach ward had the largest number of respondents at 24.9% and the least number of participants was from S.E Nyakach at 16.1%.

About 91% of the aggregate extractors were informally employed while the remainder 9% was formally employed people who engaged in sand extractions to limit construction cost of their own structures or did so to supplement their incomes from other sources. The employed segment of the population also hired people to extract aggregate on their behalf on their own land to avoid purchasing the sand at an exorbitant cost. A majority of the extractors engaged in the activity for most of the year with the intensity fluctuating with demand and seasons. The rainy season came with demand for quality river deposited sand and with this came severe degradation.

According to table 4.1 approximately 51% of sand extractors carried out extraction on ancestral land as 21% did so on purchased or leased land and about the same percentage extracted sand from public land. Contrariwise, studies done earlier found out that leased land experienced more degradation than the others where the owners failed to set limits to the extent of extraction (Swallow, B., Okono, A., Ong, C., & Place, F. 2003). In Nyakach the public land appeared more degraded than leased land. This was because the land owners set limits as to the extent of extraction by demarcating the extent of extraction. Besides, most owners determined where the extraction took place.

Characteristics	Frequency	Percentage	Characteristics	Frequency	Percentage
Gender			Marriage		
Male	268	89.9	Single	145	48.7
Female	30	10.1	Married	153	51.3
Age			Land in acres		
≤18	30	10.1	0-1	72	24.2
19-25	42	14.1	2-3	130	43.6
26-30	57	19.1	4-5	39	13.1
31-35	58	19.5	6-7	19	6.3
36-40	39	13.1	8-9	14	4.7
41-45	31	10.4	10-11	10	3.4
46-50	21	07	≥12	04	1.3
51-55	12	04	Land tenure		
≥56	08	2.7	Purchased	27	9.1
Mean age	29		Leased/rented	63	21.1
Education			Ancestral	152	51
Primary	119	39.9	Public	60	20.1
Secondary	130	43.6	Residence		
Tertiary	49	16.4	West	67	22.5
Occupation			North	59	19.8
Formal	25	8.4	Central	73	24.9
Informal	273	91.6	S. East	48	16.1
			S. West	51	17.1

Table 1: Socio-demographic Characteristics of the Respondents (n=298)

Source: Researcher's field data, 2018

Source: Researcher's field data, 2017

Figure 1 depicts a comparison of sand extraction by percentage between the sand extracting wards in Nyakach sub-count; West Nyakach 67 people, North 59 people, Central 73 people, S.E Nyakach 48 people and S.W Nyakach 51 people.

Figure 1: Pie Chart on Comparison of Aggregate Extraction by Wards, 5 Wards n=298
Researcher's field data, 2017

Based on the results presented in figure 1, Central Nyakach recorded the highest number of sand extractors at about 25% followed by West at about 23% and North at 19%. The least number of extractors was from S.E Nyakach. The large number of sand extractors in Central Nyakach was attributed to the relatively larger population of unemployed youths and explains why central Nyakach was the most degraded section in Nyakach sub-county.

Season	No. of Trucks	Frequency	%	Approx. Total Trucks
Dry(dry pit extraction)	40-44	24	8.3	1008
	45-49	21	7.0	987
	50-54	19	6.4	988
	55-59	15	5.0	855
	60-64	12	4.0	744
	65-69	8	2.7	536
		99	33.2	5118
Wet (Wet pit extraction)	40-44	41	13.8	1722
	45-49	38	12.8	1786
	50-54	31	10.4	1612
	55-59	25	8.4	1425
	60-64	21	7.0	1302
	65-69	17	5.7	1139
Wet season total		199	66.8	8986
Annual total		199	100	14,104

Table 2: Extracted Sand in Trucks in Two Seasons for Nyakach n=298.
Researcher's field data 2017

Of the 298 respondents, about 33% of sand extractors extracted about 5118 trucks of sand in the dry season and about 8986 trucks in the wet season as depicted in table 4.2. This indicated that a lot of sand ripped from the surface of land was appropriated by humans exerting a negative influence on land and affecting the quality of resultant land as observed by Hooke, (1994). Stream channel incision was experienced more in the wet season when more sand was extracted from the channels exposing the bare channel floors to more erosion in the subsequent water flows.

In the dry season the sand extractors carried out dry pit extraction while in the wet season wet pit extraction took precedence. Dry pit sand extraction was carried out mainly on the riparian zones and on range lands ripping off the vegetation cover and digging up sand pits all over the land. The high number of open pits inhibited viable economic activities and reduced the ability of land to provide essential services. Visual indicators of degradation such as wide gullies, incised channels and unplanned open pits characterized the region. These attributes make Nyakach one of those severely degraded regions as classified by (FAO/AGL, 2005). The findings in this study conforms to the observations made in a previous study in the Northern region of Ghana and East Gonja district where sand winning had led to massive land degradation (Musah 2009).

Unplanned open pits and widening gullies are indicators of land degradation as observed by since they alter the shape of the resultant landscape and its inherent biodiversity (Corey et al., 2007).

Figure 2: Open Sand Pits Filled with Water during the Rainy Season of 2017 in Central Nyakach

Source: Researcher, 2017

The open sand pit partially filled with water on Plate 4.2 was the result of dry pit sand mining on farms and range lands that riddled the land with sand pits indicative of degrading land. Besides the unplanned open pits, vegetation was also removed ahead of the extraction rendering the soils bare and susceptible to erosion since vegetation plays an important role in protecting soils from erosion (Hagos, 1958; Morin 1963). A gap exist in earlier observations by Kodiwo and Ang'awa, (2012) citing the main cause of land degradation as erosion. According to this study, prevalent pervasive sand extraction strips the land of vegetation, loosens soil particles, opens up pits, widens gullies and carries sand away leaving the land in an already degraded state and more susceptible to erosion by vagaries of weather making it a significant cause of Land degradation in Nyakach.

Encroachment margins on table 4.3 are average decreases in distances between sand mines and homes or farms as reported and observed. The researcher's own model $10yp - C_p = E_m$, was used to gauge encroachment rate, where 10yp is proximity 10 years ago, C_p is current proximity and E_m is the encroachment margin.

Proximity Margin in Meters	Frequency	Percentage
5-10	80	26.8
11-15	57	19.1
16-20	55	18.5
21-25	50	16.8
26-30	30	10.1
31-35	11	3.4
36-40	9	3
≥41	6	2
Total	298	100

*Table 3: Extraction Encroachment Margin over 10 Years in Nyakach n=298
Researcher's field data 2017*

Proximities margin column on Table 3 shows the margin difference between previous proximities of extraction site and current ones to residences and farms where about 27% of the respondents reported loss of viable land by horizontal distance of between 5-10 meters as a result of aggregate extraction. The least number of respondents, 2%, recorded greatest loss of land of over 41 meters by horizontal distance. The decrease in the distances between sand extraction sites and home and farms meant loss of arable land to aggregate extraction as depicted in table 4.3. Besides losing arable land, vegetation cover was also lost alongside, findings which conform to findings of previous study on loss of arable land to human activity (Musah 2009).

The average loss of arable land was 18m in 10 years giving an average horizontal loss rate of 1.8m of land per annum or approximately 2m per year. The assumption was that all homesteads remained in their original positions in the ten year duration and that there were no additional homes. The loss of arable land in this study is corroborated by data provided by the Sub County agriculture office which showed that in slightly over four decades this area of Nyakach had lost about 30% of land covered in vegetation to land use activities yet the effect of cultivated land was seen to be minimal by sheer size. While cultivated land size doubled by percentage, the sheer size was much less than the size of the resultant bared land.

Pearson's product moment correlation coefficient determination of the relationship between extraction encroachment margins and extraction pit depths yielded a correlation (r) value of 0.95 and a coefficient (r^2) value of 0.90 indicated a stronger positive relationship between sand winning and severe land degradation which were significant indicators of land degradation.

X	Y	XY	X ²	Y ²
7.5	1.5	112.5	56.25	2.25
13	3.5	47.25	169	12.25
18	5.5	99	324	30.25
23	7.5	172.5	529	56.25
28	9.5	266	784	90.25
33	11.5	379.5	1089	132.25
38	13.5	513	1444	182.25
43	15.5	666.5	1849	240.25
Σ 203.5	68	2256.25	6244.25	746
Mean. 17.7	7.1	282	780.5	93.25

Table 4: Pearson's Moment Correlation Coefficient Values, x-Encroachment Margin, y-extraction pit depths

Researcher, (2017) $r = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2 \sum(y-\bar{y})^2}} = \frac{513.36}{534.8} r = 0.959$

$$\frac{\sum(x-\bar{x})^2 \sum(y-\bar{y})^2 = 513.36}{534.8} r = 0.959$$

The correlation (r) value of 0.959 indicated a stronger positive relationship between horizontal encroachment and vertical removal of aggregate thereby eating into the land in the region. The stronger relationship points to the severity or magnitude of encroachment and perhaps the urgency with which degradation caused by sand extraction should be addressed. The findings here were in concomitance with those of (Surender Singh Chauchan, 2010).

Indigenous trees, long grass on Nyabondo plateau, short grass and shrubs were all on a decline in Lower Nyakach. Exotic trees species; Taminalia brownie and Croton megalocarpus, E. Saligna and E. grandis respectively all declined too confirming the degrading effects of sand winning.

Vegetation type/species	Decline/increase	Location
Grass	-	
Short grass	-	Lower Nyakach
Long grass	-	Nyabondo plateau
Trees	-	
Indigenous	-	
Taminalia brownie	-	Lower Nyakach
Croton megalocarpus	-	Lower Nyakach
Exotic		
E. saligna	±	S.E/S.W Nyakach
E. grandis	±	S.E/S.W Nyakach

Table 5: Vegetation Dynamics in Relation to Sand Extraction, key - for decline, + for increase
Researcher, (2017)

Among the vegetation varieties on decline were the indigenous species of trees, taminalia brownie and croton megalocarpus that characterized the Lower Nyakach region. These tree species were known to be well adapted to the prevailing weather conditions in the region. In West, Central and North Nyakach several trees of taminalia brownie and croton megalocarpus species were cut down to pave way for accessing sand mines and eventually ended up as fuel wood rendering conservation ineffective. Sand extraction was therefore considered a threat to survival of plants in the region conforming to earlier studies on effects of sand mining on vegetation (Anand, 2006).

Plying the same roads over years coupled with extraction sand on the sides of the roads had caused a parallel shift of roads with sand mine encroachment direction. Shifting infrastructure such as roads was an indicator of land degradation.

Drainage Channel	Shift Distance (meters)	Shift Duration (years)	Shift Direction	Location
Omondo	15-45	3	Parallel	C.Nyakach
Katukodeyo	15-45	5	Parallel	N.Nyakach
Kusa	10-35	3	Parallel	West
Ragen	10-30	3	Parallel	C.Nyakach
Bugo	15-40	5	Parallel	West
Asawo	7-25	4	Parallel	C.Nyakach

Table 6: Migrating Rural Access Roads with Encroachment Direction in (3-5 years)

Sources: Researcher's field data, 2017

According to table 6, roads along drainage channels in Central Nyakach shifted by longer distance in relatively shorter duration than those of other regions. In west and North Nyaka Ch roads shifted by a longer distance over comparatively longer duration than those in Central Nyakach. In Central Nyakach, and parts of West Nyakach the shift took

a relatively shorter time of 3 years indicative of a higher rate of degradation compared to the other region where it shifts took five years and over. As in Lome, Togo where increased traffic emanating from sand and gravel transportation continues to degrade roads and other infrastructure (Ayenagbo et al., 2011), the degrading and shifting state of rural access roads in Nyakach is indicative of degrading land.

From the land satellite image, figure 3, drawn in January 2018 from Google earth pro software coverage, the converging red arrows show the positions of both current and former rural access road. The former positions of the road have shifted parallel to the Omondo drainage channel. Plate 4.4 is a ground photo depicting positions of both former and current roads on the actual ground at an abandoned sand mine corroborating data on figure 3 of dilapidated infrastructure which were common were strong indicators of degrading land In Nyakach Sub County.

Figure 3: Lands at Image of Shifting/Migrating Roads along Omondo Channel in Central Nyakach

Figure 4: Ground Oblique Photo Showing the Shift of Road from an Extraction Site

Source: Researcher's field data 2018

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