DETERMINATION OF VEGETATION AND RELIEF THRESHOLDS FOR GULLY INITIATION IN KEREKE WATERSHED OF THE LOWER BENUE TROUGH

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ABSTRACT
Gully erosion is a serious environmental problem causing lot of havocs to the global environment including Kereke Watershed of the Benue Trough. This study therefore determines the thresholds of vegetation and relief parameters as intrinsic threshold factors for gully initiation in the Kereke Watershed of the Benue Trough, to enhance gully erosion control. The systematic sampling procedure was used to select thirty-two settlements in the study area as catchment areas for data collection. Data on vegetation, relief parameters and gully intensity/frequency were collected from direct field measurements and participatory observation. Percentages and means were used to depict variations in the data set. Plot scatter graphs were used to establish the relationship between vegetation, relief and gully frequency/intensity to determine threshold values for gully initiation. Findings of the study shows that the critical thresholds of 69% for vegetation cover, 5cm for depth of litter cover, 2^o for valley slope angle and 71m for elevation above sea level, are essential for gully initiation in the Kereke Watershed. The study established that Kereke watershed exceeded the threshold values of vegetation cover, depth of litter cover and slope gradient for gully initiation, and therefore gullies were incised in some parts of the watershed. It is therefore recommended that government and individuals should engage in afforestation by planting of trees to help improve vegetal cover, depth of litter cover and slope stability in the study area.This will help to reduce the intensity of gully initiation in the study area for enhanced environmental management.

Key words: *Gully initiation, Kereke Watershed, relief, thresholds, Vegetation*

INTRODUCTION

Gully erosion poses severe problems to the global environment. Pimental (2006) noted that gully erosion is a very serious environmental problem causing lots of havoc to people in different places. Gullies develop as a result of accelerated erosion in disturbed watersheds; and it is a critical problem of the Nigerian environment as reported by Faniran and Jeje (2000).Udosen (2000), Songu, Oyatayo and Iorkua (2015) observed that gully erosion is an important soil degradation process in a range of environments especially within the humid tropics, causing considerable soil loss and producing large volumes of sediment downstream due to high rate of surface runoff. Gullies are also, effective links for transferring runoff and sediment from uplands to valley bottoms and permanent channels where they aggravate offsite effects of water erosion like flooding and river poisoning (Fubara, 1988).

Soil erosion is triggered when the threshold conditions or limit values of environmental factors are exceeded (Charlton, 2008). Threshold is therefore the point where a system's behavior changes from normal to a new set of behavioral pattern (Charlton, 2008). Threshold can be influenced by internal factors such as geologic formation, soil, relief or external factors such as climate, base level and anthropogenic activities. The most common threshold in an environment is soil threshold or resistance of surface materials and water flow or wind velocity for particles and sediment transportation. Gully erosion generally has some thresholds including topographic thresholds, geomorphic, climatic, hydraulic and vegetation thresholds among others. These thresholds help in understanding how changes in watershed parameters influence the initiation of gullies in a drainage basin (Katz *et al.*, 2013). Also, Schumm (1979) opined that identifying threshold conditions of geomorphic phenomena helps in providing explanation for the emergence of landforms; and also to identify insipiently unstable landforms and predict changes that may occur in them.

Charlton (2008) noted that understanding the internal and external thresholds of fluvial systems such as gully erosion serve as guide to the feedback mechanism of such systems. This in turn, is helpful in controlling the extent of landscape evolution due to erosion processes. Feedback therefore, occurs when a change in one variable leads to a change in one or more other variables; which acts to either counter-act (negative feedback) or reinforce (positive feedback) the effects of the original change (Charlton, 2008). Fluvial systems like gully erosion often experience positive feedback, resulting from reinforcement of the effects of the original change caused by both internal and external factors. This becomes detrimental to environmental sustainability; once the threshold points of such controlling factors are exceeded (Charlton, 2008).

Schumm (1979), Ebisemiju (1989), Udosen (2000) noted that in a given landscape, whether a gully is initiated or not, depends on the extent of the alteration of vegetation cover, slope length, slope gradient, nature of earth materials; all of which combine to determine the resistance of earth materials to the tractive force of runoff and other fluvial processes such as soil erosion. The above observations indicate that the process of gullying is dependent on certain critical and boundary conditions of environmental factors; depending on a complex combination of such factors in a given environment. The observed current situation in the Kereke Watershed is that, the incidence of gully erosion has increased to disastrous level in some parts of the basin, especially in North Bank area, Agan, Daudu, Yerewata, Agyaragu among others; which has resulted in the destruction of farmlands, houses and roads. However, literature review indicates paucity of knowledge regarding the threshold values of vegetation and relief parameters as internal threshold factors for gully initiation in the Kereke watershed which ought to be useful for gully erosion control measures. It is against this backdrop, that this paper established thresholds of vegetation and relief parameters for gully initiation as its aim, to bridge literature gap and enhance environmental sustainability.

The aim of the study was achieved through the following objectives:
(i) To determine the threshold values of vegetation characteristics for gully initiation in Kereke watershed
(ii) Ascertain the threshold values of relief parameters for gully initiation in the study area.

THE STUDY AREA

Kereke watershed of the lower Benue Trough lies between latitude $7^{0}36^{I}$N and $8^{0}20^{I}$N and between longitude $8^{0}28^{I}$E and $8^{0}50^{I}$E (Ministry of Lands and Survey Makurdi, 2016). The Kereke watershed like other parts of the Benue Trough experiences wet and dry climate known as "Aw" by Koppen's climatic classification scheme. This type of climate is also called the tropical humid savanna climate (Tyubee, 2005). The wet season which last for seven months starts from April and ends in October. Conversely, the dry season starts from November and ends in March. The climate is usually associated with torrential rainfall and high temperatures. The annual total rainfall ranges from 1000mm to 2000mm, with an average annual intensity of 44.85mm/hr (NIMET, 2015).

Temperatures are high throughout the year, averaging 27^0c to 31^0c. Though, it may occasionally rise to 37^0c in some days in March and April. The study area is confined in the Guinea Savanna region of the Benue valley. It is therefore characterised with shrubs, grasses and trees. Some of tree species in the study area include: Raphia palm (*Raphiasudanica*), sheabutter trees (*Butrospernumparadoxum)*, Malina (*Gmelinaarborea)*, Obeche (*Afzetia Africana*), locust bean trees, Mahogany, Iroko trees. Other economic trees found in the study area are Mango (*mangiferaindica)*, Cashew tree (*Anacardiunaccidentale*), Guava (*Psidiumguajava*), Pawpaw (*Caricapapaya*), Palm tree (*Elaeisguinniensis*), Banana (*Musaspp)* and Sweet orange (*citrussinensis*).

The geology is predominantly sandstone. The sedimentary basins found within the Benue trough aulocogen comprises of older and younger sedimentary rocks formed between Paleozoic and Cenozoic era of geologic time scale (Benkhelil, 1989). The superficial geology of the Benue trough is largely meta-sediments, predominantly comprised of alluvial deposits made up of sand, clay, silt, gravel and pebbles and forms the dominant surface geology of the study area (Benkhelil, 1989). The study area is endowed with erodible soils, which are predominantly deep, sandy and are derived from alluvial deposits. The soil is well drained and so the water holding capacity is limited; and more so, because the soil has moderate organic matter content which enhances permeability (Aneke, 1991).

The Kereke watershed has an undulating terrain with slope angle exceeding 10^0 in some steep areas. Its general topography varies between 69m – 255m as analysed from Satellite Imagery (SRTM) of the study area. The Kereke watershed is a 4th order drainage basin, with a total of fifty-nine 1st order streams, twenty-seven 2nd order streams, twelve 3rd order streams and one 4th order stream. The Kereke watershed has an average bifurcation ratio of 5.48. The moderate bifurcation ratio could be attributed to the sedimentary rocks which underlain the basin and moderate rainfall intensities. The mean bifurcation ratio of 5.48 implied that the dissection of the Kereke drainage basin is coarse and this could influence channelised flow especially at the lower segment of the basin and thereby influencing gully initiation in some parts of the basin. Figures 1 and 2 are location and relief maps of the study area.

Fig 1: Location of Kereke watershed

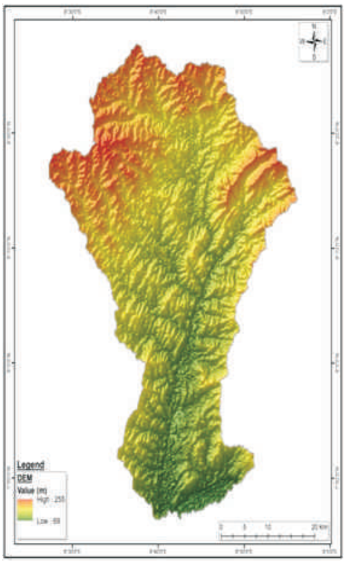

Fig.2: DEM of Kereke watershed showing variation in relief

Source: Authors' GIS Analysis from SRTM, 2018

METHODOLOGY

The field observation design with emphasis on direct field measurements was adopted in this study. Sample size for the study was determined by using topographic map sheets Makurdi 251 NW, Makurdi 251 NE, Makurdi 251 SW and Makurdi 251SE at the scale of 1:50,000; published by the Federal survey of Nigeria in 1970 (Office of the Surveyor General of Nigeria, 2016). The entire Kereke watershed which is 372.41km^2 identified on the map, was covered with network of grid lines at interval of 1cm; which represented 500m on the ground. All the grids were then numbered; and the total number of grid cells covering the drainage basin were 62; representing the sample frame. The systematic sampling procedure was then used to select 32 grid cells at every second grid cell, which represented interval of 1km^2 for data collection. The systematic sampling procedure was achieved by selecting the grids with even numbers, and with a starting point of 0. Location of the sampled grids is shown in Table 1.

Table 1: Location of sampled grids

S/N	Selected Grid Number	Settlement (catchment area)
1	0	Low cost housing, North Bank
2	2	Agan
3	4	Daudu
4	6	Ikpam
5	8	Gide
6	10	Iyorkyaa
7	12	Akiki
8	14	Kwabo
9	16	Gever
10	18	Asamakaha
11	20	Ukpiam
12	22	Ajo
13	24	Kyaan
14	26	Usan
15	28	Amala
16	30	Agena
17	32	Hinyam
18	34	Yerewata
19	36	Ande
20	38	Kyado
21	40	Kadarko
22	42	Akumba
23	44	Gogo
24	46	Achuwa
25	48	Gaval
26	50	Giza
27	52	Ume
28	54	Adobi
29	56	Aloshi
30	58	Agyaragu
31	60	Adugu
32	62	Agaza

Source: Authors' Analysis, 2018

Data needs on vegetation and relief parameters were collected as follows: information on vegetation was sourced from field measurements using survey equipment. Vegetation parameters needed were vegetation cover and litter cover, which were measured and expressed in percentage and centimeter (cm) respectively. Vegetation cover was determined using visual estimation method by measuring the extent of the leave coverage on ground in meters using a measuring tape. Depth of litter cover was measured by digging through the soil using a hand trowel and measuring the depth of litter cover with a ruler. Relief parameters such as valley slope angle and elevations were also measured on the field using an Abney Level and a hand-held Global Positioning System (GPS) Germin 12 version and expressed in degrees and meters respectively. Field measurements were done as shown below.

(I) Vegetation cover: Vegetation is an assemblage of plant species and the ground cover they provide by extension of their branches and leaves is referred to as vegetation cover (Charlton, 2008). It is importantto note that in erosion research, it is imperative to know the proportion of the ground that is covered, especially near the ground. This gives the measure of the ability of vegetation to intercept raindrops or alternatively; the proportion of bare ground open to direct rain drop splash. The method that was used to measure vegetation cover was the visual estimation method, using quadrate size of 10m x 10m. Because of the large size of the quadrate, vegetation cover was measured at two different areas within each of the 32 sampled areas. The choice of the large quadrate size was based on the cleared vegetation in some parts of the basin. This was to enhance the availability of different trees and shrub species for observation and measurement and average vegetal cover was then computed.

The visual estimation method was adopted because it was fast, required no specialised equipment, and was adapted on plants of various growth forms. The vegetation cover was determined as an estimate of the area of influence of the plant leaves and canopyor by estimating the area of a quadrate that is covered by a plant's canopy. It was calculated by measuring the extent of the leave coverage on ground in meters, divided by the total quadrate area and multiplied by 100 percent.

(ii) Litter cover: Litter cover is dead plant materials that have fallen to the ground surface. This detritus or dead organic material and its constituent nutrients are added to the top layer of soil (Brady and Weil, 2000). The depth of litter cover for each sampling area was measured with the aid of a ruler by digging through the soil at the depth of 30cm and expressed in centimeters. Two measurements were taken in each of the sampled grid and average was then computed for analysis

(iii) Valley slope gradient: This is the gradient or inclination of an area along a slope profile from upslope to downslope (Young, 1972).Valley slope gradients in the sampled grids were measured using the methods devised by Young (1972) using random sampling method. Slope angles were measured within each sampled area using an Abney Level and expressed in degrees..

(iv) Elevation (Relief): The elevation of a geographic location is its height above or below a fixed reference point, most commonly a reference geoid or Earth's sea level as an equipotential gravitational surface (Charlton, 2008). The heights above sea level in the study area were determined in each of the thirty-two sampled settlements using a Global Positioning System (GPS) GERMIN 12 version. The hand held GPS was switched on, allowed to receive signal and then placed on the ground where the measurement was to be taken in each of the sampled settlements. In gullied sites measurements were taken 5m away from the gully channel, to identify the critical relief associated with the gully development.

(v) Gully frequency/Intensity: This is the number of gullies incised in an area. In geomorphological study, it is used as a measure of the extent of gully initiation as reflected by the intensity or frequency of the gully erosion channels. The gully frequency/intensity in the study area was determined as the number of gully channels per square kilometer (Udosen, 2008).

Data collected was analysed using descriptive statistics such as percentage and mean to ascertain variation in the data set and presented in tables. Percentage was computed using the formula:

$$\frac{n}{\Sigma N} \times 100 \quad (1)$$

In the formula, n, is the value of each individual score and ΣN is the sum of the all the scores.
Mean was calculated using the formula:

$$\frac{\Sigma N}{n} \quad (2)$$

where Σ N, is the sum of all the value observation and n, is the number of observation.

The independent variables that were used to determine thresholds of gully erosion initiation in this research were: vegetation and relief characteristics. The dependent variable that was used is gully frequency or intensity. The Microsoft excel software was used to plot the scatter graphs for independent and dependent variables. The point where the slope of the regression line (b) cut or interfaced with the x-axis represented the threshold value of the independent variable. One of the major limitations of Microsoft excel software was that, points along x and y axis with the same value were plotted as one value, instead of repeated plottings. Therefore, in most cases fewer than expected points were shown on the scattergrams.

RESULTS AND DISCUSSION

Thresholds of Vegetation Characteristics for Gully Initiation in the Study Area

Data on vegetation characteristics were collected on vegetation cover and depth of litter cover. The results are presented in Table 2.

Table 2: Vegetation cover, depth of litter cover and Gully frequency in the studyarea

Serial Number of Sampled Areas	Vegetation cover (%)	Depth of litter cover (cm)	Gully frequency/intensity
1	38.9	1.4	1.0
2	41.9	4.8	1.0
3	43.5	1.5	1.0
4	50.2	2.8	0.0
5	39.3	2.7	0.0
6	51.0	3.4	1.0
7	70.5	3.5	0.0
8	53.2	2.7	1.0
9	66.9	2.4	0.0
10	52.2	2.3	1.0
11	41.8	2.7	0.0
12	55.9	2.3	2.0
13	43.7	1.7	0.0
14	41.5	3.3	1.0
15	56.2	2.9	1.0
16	51.9	2.4	0.0
17	45.9	2.5	0.0
18	48.8	2.6	0.0
19	55.6	3.5	1.0

Serial Number of Sampled Areas	Vegetation cover (%)	Depth of litter cover (cm)	Gully frequency/intensity
20	62.9	3.0	0.0
21	58.8	5.3	0.0
22	64.5	4.2	0.0
23	54.3	2.2	1.0
24	65.7	2.0	0.0
25	49.1	2.3	1.0
26	46.8	2.6	0.0
27	53.8	2.4	0.0
28	71.0	1.9	0.0
29	48.6	2.0	1.0
30	47.0	2.5	1.0
31	54.8	5.2	0.0
32	60.8	3.5	0.0
Total	**1686.2 (%)**	**89.7 (cm)**	**15**
Mean	**52.7%**	**2.8cm**	

Source: Authors' field work, 2018

The results presented in Table 2 contains information on vegetation cover and depth of litter cover as measured in the field in the course of this study. Table 2 also contains the computed average values of vegetation cover and depth of litter cover in the study area. Available results on vegetation cover indicated that the mean value of vegetation cover in the Kereke watershed is 52.7%. The moderate mean value of vegetation cover showed that, the area is endowed with secondary vegetation of different trees and shrubs species that produce moderately large vegetation canopy for shielding the ground surface from direct raindrop impact. It is therefore obvious that where vegetation cover is large, rainfall droplets are likely to be intercepted by the leaves of the plants; and this has implication on the energy exerted on the earth surface at any given time in relation to gully initiation.

Results on depth of litter cover contained in Table 2 shows a mean value of 2.8cm. The mean depth of litter cover in the Kereke watershed is considered moderate. Litter cover plays a significant role in gully erosion control, where there is huge deposit of litter within the upper layer of the soil profile, the tractive force of surface runoff is reduced. At the initial stage of soil erosion development, in form of sheet erosion through rill and subsequently gully erosion, the depth of litter cover helps to limit the development of these erosion stages by way of providing the organic matter in form of humus needed to bind the soil particles together thereby improving infiltration into the soils, its cohesiveness, thereby reducing its erodibility.

It was observed in the field during this research, that most of the litter cover was in form of semi-decayed leaves, freshly deposited leaves, remains of animals and decomposed organic contents. This could be the rationale behind the moderate depth of litter cover in the Kereke watershed, as most of the organic matter contents were found not to be completely decomposed; and therefore could not be carried down the soil profile.

Scatter graphs were plotted using the data in Table 2 in Microsoft excel software to determine the threshold values of vegetation parameters for gully initiation in the study area. Figure 1 is a scattergram showing the relationship between vegetation cover and gully frequency vis-à-vis the threshold value of vegetal cover for gully initiation in the study area.

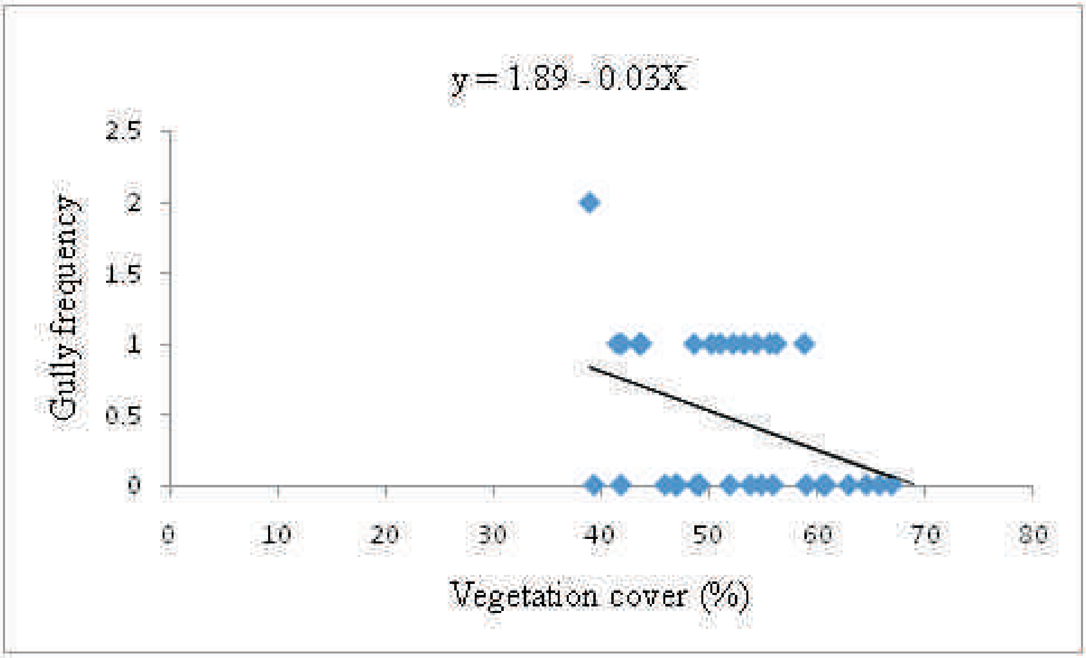

Figure 1: Scattergram showing the vegetation cover and gully frequency
Source: Authors' Analysis, 2018

Fig. 1 shows that the threshold value of vegetation cover for gully initiation in the Kereke drainage basin is 69%. This was determined using the point where the slope of regression line or line of best fit cuts the X-axis on the line of independent variable (vegetal cover). The negative slope of regression line of best fit indicated that gully erosion is likely not to be initiated if the threshold value of vegetation cover is met and vice versa. Therefore, the threshold value for vegetation cover of 69% is considered the minimum value of vegetal cover in the study area that could be sustained for controlled gully initiation in the study area. Notwithstanding, vegetal cover of 40% to 65% as shown on the scattergram are critical values for gully initiation in the study area, just before the threshold condition is met. This is evident in the study area, as some of the selected settlements are incised with gullies, except areas that the threshold value of vegetal cover has not been met such as Akiki and Adobi settlements (Table 2).

The threshold value of vegetal cover for gully initiation in the study area is considered high; and this could be attributed to the nature of the superficial materials and the nature of the soils in the area. Once this threshold of vegetal cover is not exceeded gully erosion may not to be initiated in Kereke watershed. This was observed in settlements such as Akiki and Kadarko. In settlements where thresholds were exceeded such as Federal low cost estate, Agan, Kwabo, AJo, Usan, Ande, Gogo among others were found to be initiated with gully erosion (Table 2). This was attributed to reduced vegetal cover in Agan, Kwabo, Ajo, Usan, Ande, Gogo and the nature of soils and geology of the area which is made up of predominantly sandstones.

The limiting value of 69% vegetal cover demarcated gullied areas from ungullied areas in the study area. The threshold values of vegetal cover for gully initiation in the study area is lower than values obtained in other places. For instance, Udosen (2000) reported an inverse relationship between vegetal cover and gully frequency, with a higher threshold of vegetal cover of 72.5% for gully initiation in AkwaIbom State of Nigeria; and this was attributed to high intensity of rainfall in the area. The threshold value of vegetation cover (69%) in the

Kereke watershed approximated and agreed with the results reported by Udosen (2000) in AkwaIbom State. This was based on the similar and sizeable nature of tree species found in the tropical Savannah environment of the Kereke watershed such as Malina (*Gmelinaarborea)*, Obeche (*Afzetia Africana*), locust bean trees, Mahogany, Iroko trees which are also found in the tropical rain forest of AkwaIbom State. However, Fen-Li Z heng(2016) reported lower threshold vegetation cover of 50% in China; and it was attributed the soils and moderate rainfall intensity in the study area. The high threshold value of vegetation cover (69%) observed in the study area is capable of protecting the ground surface from severe gully erosion initiation. This is because a high amount of vegetal cover in an area reduces the effect of direct raindrop impact, sediment loss and the tractive force of runoff that could enhance gully erosion initiation. Figure 2 is a scatter graph showing the threshold of depth of litter cover for gully initiation in the study area.

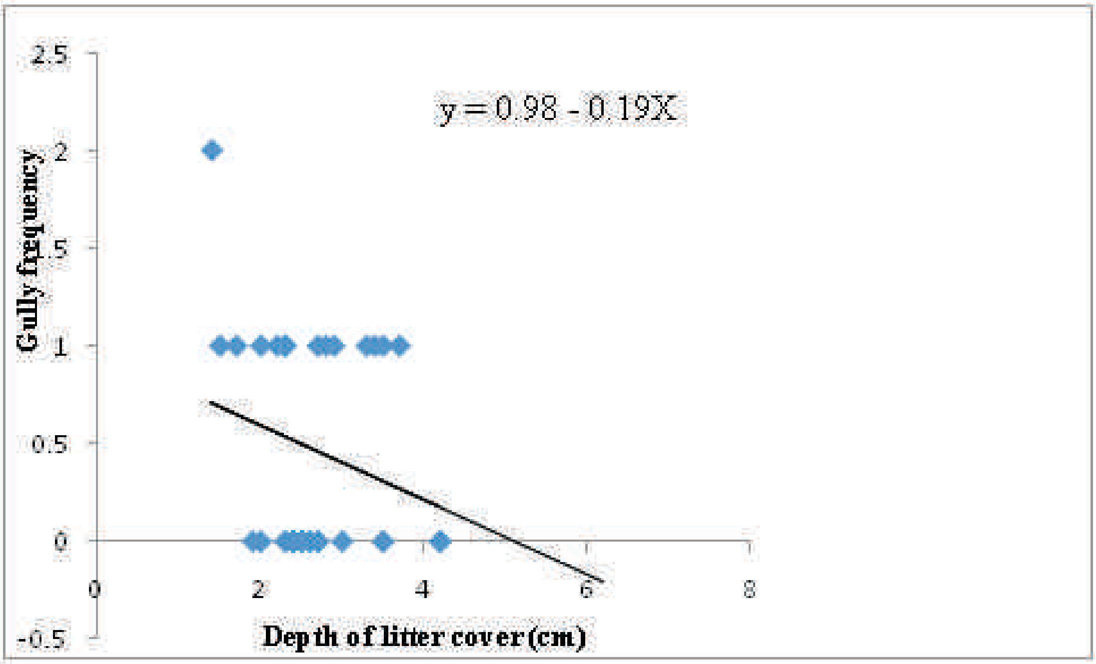

Figure 2: Scattergram of the litter cover and gully frequency
Source: Authors' analysis, 2018

The scattergram in Figure 2 shows that threshold value of depth of litter cover for gully initiation in Kereke drainage basin is 5cm. The negative slope of regression line indicated that gully erosion is not likely to be initiated if the threshold value of depth of litter cover is met and vice versa. The threshold value of 5cm is the depth of litter cover needed to prevent the initiation of gully erosion in the study area. Once this threshold value is not met, gully erosion is triggered. It was observed in most sampled settlements in the study area that the depth of litter cover was lower than the threshold value, except in one settlement such as Adugu settlement (Table 2). The settlement was found to be ungullied, unlike other gullied settlements with lower depth of litter cover. High amount of litter cover helps to provide the soil with organic matter that binds the soil particles together and makes the soil more cohesive, enhance infiltration and thereby improving its ability to withstand the tractive force of surface runoff. The amount of decayed or semi-decayed leaves deposited on the ground surface largely constituted part of the litter cover that helped to protect the soil from been eroded.

Threshold value of litter cover was not met in most of the settlements such as Low cost housing estate North Bank, Agan, Daudu, Ikpam, Gide, Iyorkya, Akiki and Kwabo; except Adugu settlement with number where it was met (Table 4.2). Most of the settlements where the threshold value of litter cover was not met were initiated with gully erosion. The inverse relationship observed between depth of litter cover and gully frequency/intensity in the study area indicated that gullies may not be initiated if the threshold value of litter cover is met. This was observed in the Kereke watershed as gullies were found to be initiated in areas where threshold value of litter cover was not met. This finding confirmed those of *Gholami and Khaleghi (2013), who discovered that litter cover with a depth of 5.2cm played a significant role in reducing rate of sediment loss due to water erosion in the humid climate of the* Haraz River basin.

Thresholds of Relief Parameters for Gully Initiation in the Kereke Watershed

Relief parameters considered in this study for gully initiation are slope angle and elevation of areas above sea level. These relief parameters were considered based on their impact on gully initiation, in terms of influencing surface runoff and sediment entrainment down slope. Data on relief parameters are contained in Table 3.

Table 3: Relief parameters and Gully frequency in the study area

Serial Number of Sampled Areas	Slope angle (degree)	Elevation above sea level (m)	Gully frequency/intensity
1	4	97	1.0
2	5	103	1.0
3	6	105	1.0
4	2	94	0.0
5	2	95	0.0
6	4	107	1.0
7	3	87	0.0
8	6	125	1.0
9	6	70	0.0
10	8	128	1.0
11	5	103	0.0
12	9	134	2.0
13	7	94	0.0
14	8	98	1.0
15	9	126	1.0
16	3	87	0.0
17	2	71	0.0
18	4	73	0.0
19	10	98	1.0
20	7	97	0.0
21	5	95	0.0
22	2	86	0.0
23	8	102	1.0
24	7	104	0.0
25	5	85	1.0
26	3	98	0.0
27	7	89	0.0
28	7	93	0.0
29	13	173	1.0
30	12	154	1.0
31	11	134	0.0
32	13	156	0.0
Total	**203^0**	**3361m**	**15**
Mean	**6^0**	**105m**	

Source: Authors' field work, 2018

Results on relief parameters were obtained directly from the field using an Abney level and GPS. Available data on slope angle shows that the mean slope angle in the study area is 6°. This slope angle observed in the Kereke watershed could have hydrological implications for the initiation of gully erosion. Mean slope angle of 6° is moderate to enhance surface runoff which in turn could initiate gully erosion in the study area. On a steep slope greater 6° gully erosion may be initiated faster than gentle slopes; especially when the removal of surface water is concentrated in narrow channels which eventually develop into gully erosion.

Results on elevation of areas above sea level in the Kereke watershed contained in Table 3 reveals that the mean elevation is 105m. The elevation of areas within the Kereke watershed is considered moderate. The effect of this level of relief in the study area is the enhancement of positive feedbacks in the initiation of gully erosion. This is because such elevations could enhance the concentration of surface runoff downstream and thereby influencing the initiation of gullies.

The thresholds of slope angle and elevation for gully initiation were determined and the result is presented in Figures 3 and 4. Figure 3 is a scattergram showing the relationship between slope angle and gully frequency in the study area.

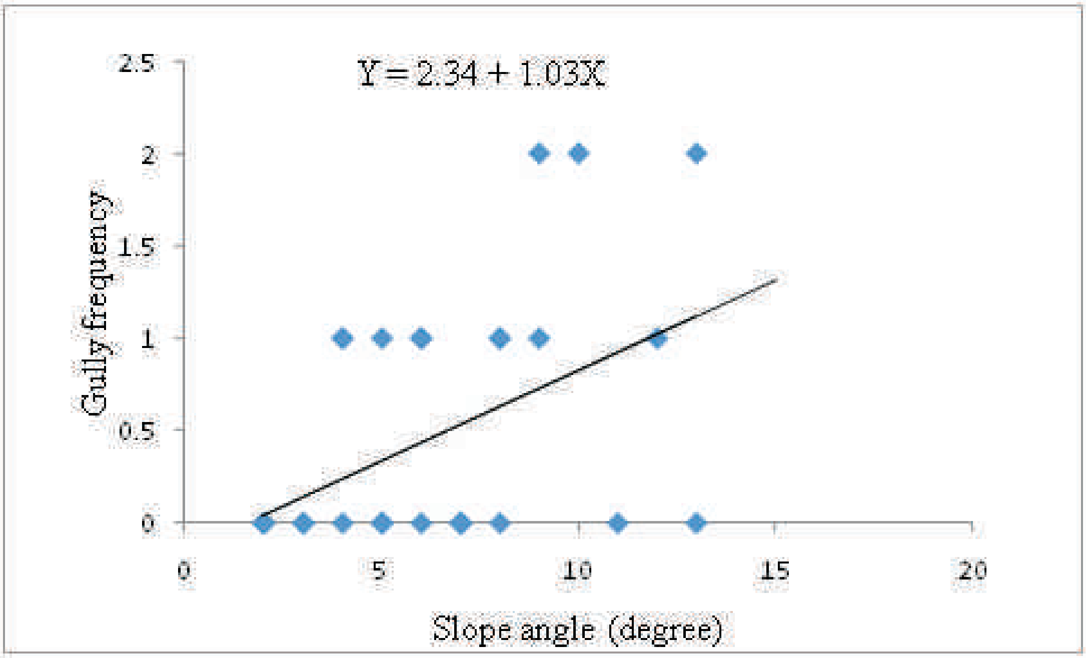

Figure 3: Scattergram of slope angle and gully frequency in the study area
Source: Authors' Analysis, 2018

The scattergram revealed a direct positive relationship between slope angle and gully frequency as indicated by the slope of regression line. This positive and direct relationship implies that gully erosion is likely to be initiated if the threshold value of slope angle is exceeded and vice versa. It is also observed that the threshold value for gully initiation in the Kereke watershed is 2°. The direct positive relationship observed between slope angle and gully frequency in the study area implies that gully erosion is likely to be initiated if slope angle exceeds the threshold value of 2°. Thus, valley slope gradients above 2° could influence the initiation of gully erosion in the area. While slope gradients below 2° will be relatively stable. This is because steep slopes enhance the concentration of surface flow, thereby creating channels in form of interrills and rills that could become gullies if left unabated; with more of the effects on steep to gentle slopes; where surface runoff is not quickly removed. Where the threshold value of 2° is not met in the study area, gullies are likely not to develop, except where other factors such as rainfall impact, soils and relief have dominated influence on gully initiation. Settlements such as Ikpam, Gide, Hinyam and Akumba are some of the areas where the threshold value of slope gradient has not been exceeded; and thereby with no gully initiated. While threshold of slope gradient was exceeded in settlements such as Low Cost housing estate, Daudu, Agan and those areas were found to be initiated with gullies.

The scarttergram also shows that slope angle of 3° to 13° are critical points for gully initiation in the study area. Settlements in the study area that are situated on such slope range are very prone to gully erosion. Some of these settlements include Agan, Asamakaha, Ajo, Usan, Agyaragu, Adugu and Agaza. However, it was observed that Adugu and Agaza settlements are not gullied; and this could be attributed to resistance of the soils to tractive force of runoff and dense vegetation cover in the area. The threshold value for slope gradient of 2° in the Kereke watershed corroborated the findings of Udosen (2000) who reported a threshold value for slope gradient of 1° for gully erosion initiation in Ikpa drainage basin of AkwaIbom State. This was attributed to the nature of the relief and superficial geology found in the two areas. Both areas are predominantly low lying covered with alluvial sediments. However, Ebisemiju (1989) reported higher threshold value of 5° for gully initiation in the humid tropical Guyana, Brazil.The relationship observed between slope gradient and gully intensity in the study area could be attributed to the sandy nature of soils and the land cover of varying types.

The scattergram in Figure 4 shows the relationship between elevation and gully frequency in the study area.

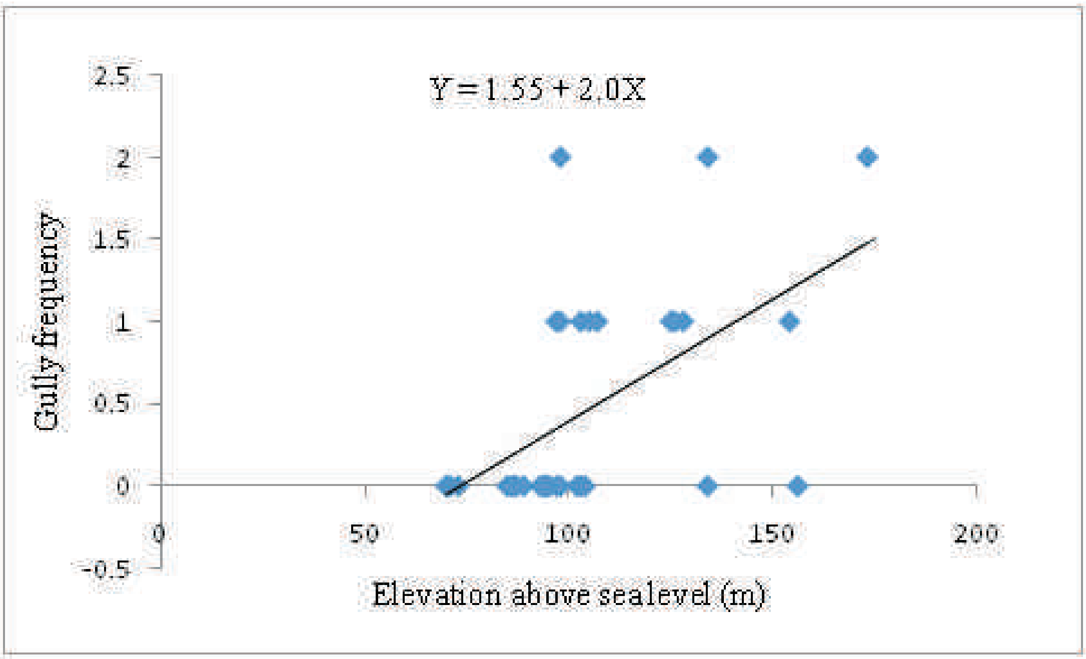

Figure 4: Scattergram of elevation and gully frequency in the study area.

Source: Authors' Analysis, 2018

The scattergram shows that threshold point of elevation for gully initiation is 71m. This threshold point is the point at which gullies are likely to be initiated in the study area; all areas lying above this threshold point are at risk of gully erosion. Hence, elevations between 72m to 150m are critical points for gully initiation in the study area. This was consequent upon the direct positive nature of the relationship between elevation and gully frequency in the study area. As elevation increases above the threshold point, gullies are likely to be initiated in the Kereke watershed. The threshold value of elevation asl was exceeded in almost all the settlements, except two settlements which are Gever and Hinyam settlements (Table 3).

These two settlements were found to be ungullied. Notwithstanding, in some of the settlements, it was observed that the threshold of elevation was exceeded but remained ungullied. Some of the settlements are Ikpam, Gide, Akiki, Kyaan, Agena, Yerewata, Giza, Ume among others (Table 3). The implication of this is that, gully erosion initiation in Ikpam, Gide, Akiki, Kyaan, Agena, Yerewata and Giza areas is not only dependant on elevation, but also a combination of initiation factors such as relief, slope gradient, vegetal cover of the area and sandy nature of the soils which collectively impacts gully initiation in Kereke watershed. Where these other factors have higher influence than elevation asl, gullies could be initiated as observed in some of the settlements such as Ikpam, Kyaan, Agena among others (Table 3).

CONCLUSION AND RECOMMENDATIONS

Gully initiation in a watershed as expressed by gully frequency/intensity is useful in assessing the extent to which environmental factors such as vegetation cover, slope gradient among others influence environmental degradation caused by gully erosion. The study established that Kereke watershed exceeded the threshold values of vegetation cover, depth of litter cover and slope gradient for gully initiation. However, along the trough variations in each of these parameters were observed. Threshold of vegetation cover was exceeded in most of the sampled settlements, except in areas such as Akiki and Adobi settlements, where the threshold hold was not exceeded, and these areas were not gullied. In settlements such as Federal low cost estate, Agan, Kwabo, AJo, Usan, Ande, Gogo among others where threshold of vegetation cover was exceeded were found to be initiated with gully erosion.

Also, threshold value of litter cover was not met in most of the settlements such as Low cost housing estate North Bank, Agan, Daudu, Ikpam, Gide, Iyorkya, Akiki and Kwabo; except in Adugu settlement where it was met and Adugu settlement was found to be incised with a gully erosion due to the inverse relationship observed between depth of litter cover and gully initiation in the study area. The threshold value of slope gradient was not exceeded in settlements such as Ikpam, Gide, Hinyam and Akumba, and thereby with no gully initiated. While threshold of slope gradient was exceeded in settlements such as Low Cost housing estate, Daudu, Agan and those areas were found to be initiated with gully erosion. Moreso, the threshold value of elevation asl was exceeded in almost all the settlements, except two settlements which are Gever and Hinyam settlements, and these two settlements were found to be ungullied. It was therefore concluded that vegetation and relief parameters have severe impact on gully initiation in the study area; and areas where threshold values of vegetation and relief parameters were exceeded, gullies were initiated.

It is therefore recommended that federal government of Nigeria should ensure strict compliance on deforestation and afforestation laws in the Kereke watershed of the Benue trough. This will help to reducing the rate of deforestation in the area and enhance increased vegetal cover and slope stability for improved environmental management and reduced gully intensity in the area. There should also be controlled cultivation along slopes to reduce channelised and concentrated peak flows that could initiate gully erosion in the Kereke watershed.

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