



Global Advanced Research Journal of Agricultural Science (ISSN: 2315-5094) Vol. 5(1) pp. 014-027, January, 2016 Issue.
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Full Length Research Papers

An Assessment of Gully Erosion in Kano Metropolis, Nigeria

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Accepted 15 January, 2016

The study was carried out to determine the effect of gully erosion in parts of Kano metropolis, fifteen gully heads were purposively selected from the study area for determining the magnitude, mechanism of gully development and head ward retreat. The development of gullies is one of the ruthless environmental problems in Kano metropolis. It has threatens urban infrastructure, properties and lives. Linear retreat of the gully heads was monitored by pegging technique. Field measurements and laboratory analysis were used in data generation. Results from the field measurements showed that gully variables (length, depth and widths) have significantly increased in the last 10 years. Laboratory analysis of soil particle size revealed that sand proportion was 73.2%, silt 14.3% and clay 11.4%. Soil chemical properties also showed that the soils are moderately acidic and contained low organic matter. The study shows that, gully heads retreated at different rates ranging from 13 cm to 121 cm depending on instability factors. Gully heads are few times steeper than angle of internal friction that introduces instability. Near vertical and overhanging slope of considerable height develop tension cracks leading to mass failure and gully head retreat. The mean area occupied by gullies from the study area stood at 42,915m², the advancement rate of gully heads ranged from 3m to 7m per year and the mean total volume of material removed as soil loss was 130,776.1m³ for the period of study. Factor analysis revealed that rainfall energy and slope steepness has the greatest influence for the occurrence of erosion in this study area. The effect of the five factors can be rated as E>F>S>L>i in accordance with their relative importance for the occurrence of erosion. This study recommend the need for scaling of gullies banks should be undertaken, in which barrages should be constructed along the principal gullies to stabilise them and stop their expansion.

Keywords: Gully erosion, Gully head retreat, soil properties, rainfall, and Kano metropolis.

INTRODUCTION

The Nigerian environment is degraded through the menace of soil erosion in several parts of the country. Part of the

result is the creation of badlands condition in many areas of the country. The menace posed by soil erosion has been

documented by many authors in many works including Ofomata (1965, 1978, 1981 and 2001), in the south eastern part of the Nigeria, Jeje (1997) Asiabaka and Boers (1988), Igbokwe, Ojiako and Nnodo (2003), Egboka (2004) in the south-western part and Ologe (1971, 1972), Bello (1983), Olofin (1987), and Patrick (1987) mentioning just a few in northern part of the country. People's life were lost to erosion, equally an average of 14862.8m³ volume of soil between 1992 to 2002 were lost to erosion (Shu'aibu, 2002 ; Suraj, 1998; and Buwa, 2003).

In areas particularly eastern part of the metropolitan Kano that include; Tsamiyar Matasa, 'Yankaba, Walalambe, Wuro Bagga, Tudun Fulani, Tokarawa, Gunduwawa, Tudun Murtala, Rimin Kebe, Gayawa, Maidile, PRP, Tsamiyar Tudun, Kawo Kureke, Dangwauro, Wailari, Yan Shana, Maradin and North Eastern by-pass are examples of areas in which erosion has led to the collapse of many houses and some are in imminent danger. Animals and children have died because of falling into deep gullies (Mallam, 2008)

Water erosion can occur as sheet; rill, and gully erosion, five Midwest states had an average of 0.89 tons of soil lost per acre by gully erosion in 1997. Comparing these gully erosion rates as a percentage of all water erosion, gully erosion accounts for 43% of soil lost (Casali, 2000). Gully erosion is the extreme case of rill erosion in which the rivulets are too large to be filled in using soil in a quick and cost-effective management method, for example disking.

Recent research has begun to focus on addressing gully issues such as the understanding of the formation of gullies, their contribution to overall soil loss, development of tools to locate channel initiation, and appropriate measuring techniques (Poesen *et al.*, 2003). The increased focus on gully research can be partially attributed to recent studies demonstrating that gully formation is very common (Gordon *et al.*, 2008) and can be as significant as sheet and rill erosion in terms of sediment yield (Bingner *et al.*, 2010). Gullies can be generally classified as ephemeral, classical, or edge-of-field. The Soil Society of America (2001) defines ephemeral gully as "small channels eroded by concentrated flow that can be easily filled by normal tillage, only to reform again in the same location by additional runoff events". As the headcut migrates upstream and the channel gets wider, faster than the interval between farming tilling operations, farming equipment is forced to operate around the gully and as result the gully becomes permanent (classical gully). Finally, as the name suggests, edge-of-field gullies are defined by channels where concentrated flow crosses earth bank (Poesen *et al.*, 2003).

The formation of gullies has become one of the greatest environmental disasters facing Kano metropolis. Hundreds of people are directly affected every year and have to be re-located. Large areas of lands are turning into badlands. Therefore, solving the gully erosion problem in metropolitan Kano requires thorough research efforts

The aim of this study is estimating volume of transported soil loss from gullies, area occupied by gullies and the advancement rate of gully heads in critical erodible areas of the study area.

STUDY AREA AND METHODOLOGY

Metropolitan Kano is located between latitudes Latitude 11°59' and 12° 02' N, Longitude 8°33' and 8°40'E (Figure 1) the study area along north eastern bypass stretches to areas behind Kano state legislative quarters in Tarauni and Kumbotso L.G, Tsamiyar Matasa-Gunduwawa and Rimin Kebe-Gayawa in Nasarawa and Ungogo Local Government in metropolitan Kano. The present climate of the region (i.e. Kano) is tropical wet and dry, classified as AW by Koppen (Olofin, 1987). The most important aspect of the rainfall of the study area is seasonality. There is no precipitation between the ends of March. There is high precipitation in the month of July and August; and associated with storms. This aspect of rainfall accelerates the collapse and removal of the sub-surface materials. Kano metropolis consists of gently undulating plains sloping to the northeast. The study area is located on basement complex rocks of Precambrian origin with rock types mainly of older granites with some intrusion of quartz feldspathic among others.

The dominant soils are the less reached, slightly acid soils derived from wind rip soils, generally shallow and coarse (Ahmed, 2003). In some parts of the study area, there is the present of hydromorphic soils which are used for "Fadama" cultivation and block construction for building purposes. The vegetation has been largely affected by human interference through, cultivation, grazing, construction and annual burning, has now reduced it to parkland. Small short trees and shrubs are more common on fallow and where regeneration may take place. About 75% of the land is cultivated parkland with average tree density of less than 25 per hectare (Ahmed, 2003). Metropolitan Kano had a total number of over 2,826,307 people with a population density of 45,592 per square kilometre (NPC, 2006). Most of the people living around the area are Hausa and Fulani and the Predominant language is Hausa. Urban Kano has been experiencing rapid growth of population since 1952. The dominant land use in the study area are residential, industrial and intensive agricultural practice mostly around the fringe

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areas like Kwana Hudu, Dangwauro, Sharada, PRP to mention but a few. Another important land use in the study area is quarrying where sand and gravels are excavated from different location.

Data used in this study were derived from field measurements and laboratory analysis. Five of the pronounced gullies profiles were purposively sampled from each three erosion site for the measurement of gully morphological variables. These gullies are second orders and has numerous first orders and cut across the study area. Soil samples were taking along the gully wall layers (top, middle and bottom) sample point per gully profiles in order to analyze the soil properties, the technique employed is in accordance with (Shu'aibu, 2002 ; Suraj, 1998; and Buwa, 2003; Lazaru, Ayuba and John (2012).The first location is at the fringe of the Metropolitan Kano which is dominated by agriculture and quarrying, Rimin Kebe is located within metropolis and is dominated mostly by residential land uses while Tsamiyar Matasa is a mixture of industrial and agricultural land uses. Field measurements of depth, length and width and come up with the total surface area covered and volume of soil loss for gullies. GPS were used in taking the co ordinate gullies in three erosion sites in the study area. Predisposing factors such as: Soil characteristics, Vegetation cover, Land use, Slope gradient and Climate (rainfall data) of 2001 to 2011were determine. Data collected were analyzed using a descriptive statistic.

The dimension (length) of the gullies was measured using steel measuring tape. The width and depth of each gully were measured at regular interval of 20meters and the length and the averages of each gully were calculated. The measurement was obtained by a team including: a recorder, pole men and an observer.

The measurement of the width was taken by extending the tape horizontally from one edge of the gully to the other to determine the top width; the measuring tape was pull tight to avoid bellowing: the same process was repeated at the bottom width. The average of the two was taken as the gully width. Three men were involved in the tape while the third person was recording the measurement using 100metre steel tape. Vegetation cover was estimated by observing the proportions of complete cover to that of bare surface in an area. The vegetation count was also taken where changes in width of the gullies occurred. Depth of the gully was taken at where changes in width of the gully occurred. The measurement was taken using levelling staff. Two men handled the exercise; one was taking reading from the instrument while the second person was holding the levelling staffs which are graduated in metres. The reading was taken from the top of the gully embankment and the second was taken inside the gully so

the difference between the two readings gives the depth of the gully.

Gully head advancement per year using qualitative and quantitative assessment inform of:

$$\text{HGA} = \frac{\text{HG} - \text{LG}}{\text{Time}} \quad (1)$$

Where: - HGA is head of gully advancement; HG is head of gully and LG represent the length gully.

The slope measurement was also taken at the slope breaks. The measurement was taken with automatic level, the equipment has telescope which is mounted on tripod stand and a levelling staff. Before taking the measurement the instrument was mounted on the tripod stand then, the instrument was set by turning a screw until the bubbles settled at the centre of the lenses.

The formula used for the calculation of gully surface area is length of gully multiply by width of gully and volume of soil loss is depth of the gully multiply by the gully surface area. This procedure was used in the measurement of gullies for estimating erosion hazard is in accordance with Horton and Smith (2006) who used the procedures of measurement of gullies in assessing erosion hazard classification, while the categorization is in accordance with Kuran, and Jung, (1961) and Kappel, (1996) who developed a scheme to classify water erosion hazard severity from visible erosion features, distribution and intensity of damage.

RESULT AND DISCUSSION

Characteristics of the Soil

International pipette method was used to perform particle size analysis for soil textural classification. The method employs the Stock's law in order to determine the size of particles. Among other factors, physical characteristics of the soil determine its erosivity. Over most of the study area the soil have physical deficiency which include the occurrence of iron capping or hard crust in some areas. This hard concretion limits rooting depth and may be exposed as a result of severe erosion. Hard surface crusting (armour layer) prevents infiltration of water, thereby facilitating runoff and making the soil droughty. Almost all the soils undergo very marked hardening during dry season, favouring great amount of runoff at the onset of rainy season. The areas related to hardness in such area appear to be related to clay content. There are presences of hydromorphic soil; laterite and stoniness in few places, drying in areas of very high sand content inhabit the soil easily removed by runoff as such highly

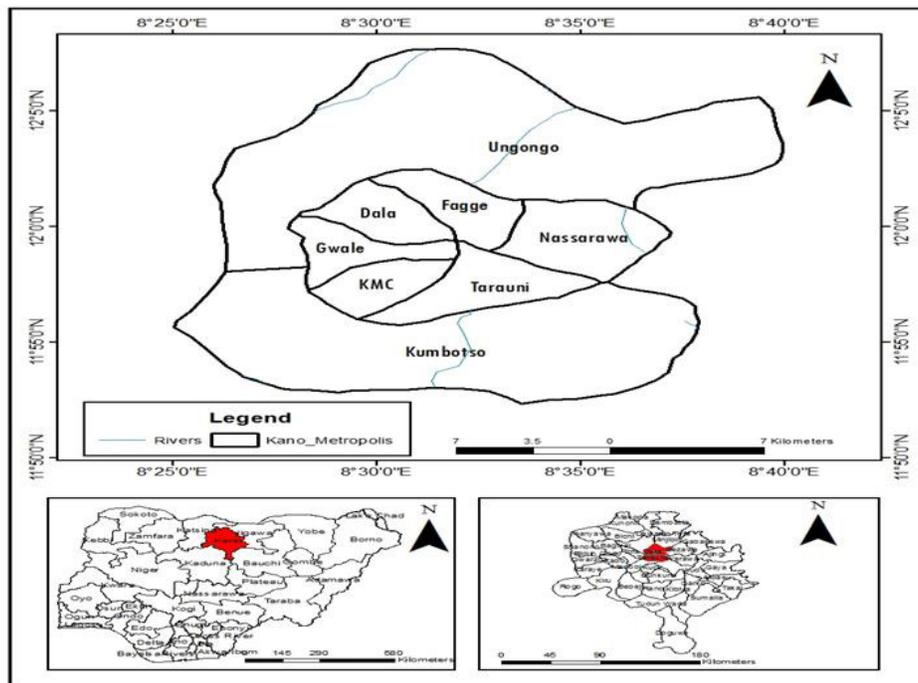


Figure 1 Map of Nigeria Showing Location of Kano State and the Study Area

susceptible to erosion. The soils in the study area vary from coarse sandy loam to loam. The overall mean proportion for the sampled gully profiles shows 73.2% sand, 14.3% silt and 11.4% clay. More than 75% of soil in the study area is significantly more of Sand (Appendix 1 shows details of the textural pattern of soil across the study area). The poor physical properties of the soil constitute a serious handicap to effective agricultural utilisation and it is highly susceptible to erosion (Ahmed, 2003).

Soil moisture content at field capacity (%) was taken, it range between 0.23 to 0.31%. The average soil pH values of the three erosion site top layer were 5.2, 6.2 and 5.1; middle layer mean values were 4.3, 5.4 and 4.6 and the bottom layer has mean values of 2.6, 4.1 and 3.7 respectively, with overall mean of 5.4 and there was no significant difference ($P > 0.05$) among the sampled gully profiles. This implied that the soils are moderately acidic. Exchangeable sodium (Na) on the other hand indicates an irregular increase and decreased in mean values from top to the bottom layer of the gully walls. The three layers showed of all the gully profiles ranges from 0.2 to 0.6 meq/100. These variations might be due to mineral constituent of urban waste disposal and the sewage that are washed away into these gully sites. The overall patterns of variation of exchangeable cation (Ca, Mg, Na and K), from top to the bottom of the gully profiles of the

three erosion site were similar. On the whole the valley bottom soils were more enriched with the basic elements, while the top or middle layer recorded the lowest mean values. This may be explained in terms of the relative steepness of the gully walls and hence downward of the basic elements and succeeding accretion at the valley floor. The results of soils organic matter content (OMC) indicate the mean value of gully site A to O (top, middle and bottom gully wall layers) ranges from 0.5 to 2.4, which is considered low. The general prototype of variation showed a downward increase in the organic contents. The organic content of all the soil samples falls below 4%, which is measured as the doorsill below which soils are erodible. Sealing and high surface runoff is also more evident in soils with very low organic content. A poor soil structure and low plant nutrient content will cause the soil to be more susceptible to gully erosion. The inference of this finding is that the soil of the study area may not be affected by micro organisms that work on organic matter which might enhance the binding of soils to resist erosivity of rainfall and runoff impact.

Iwuafor (1980) observed that, the Nigerian savanna is characterized by low phosphorus. The inference of this finding is that Most surface of Savanna soils after a number of years of cultivation become distinctively lighter and highly erodible because the fine particles have been

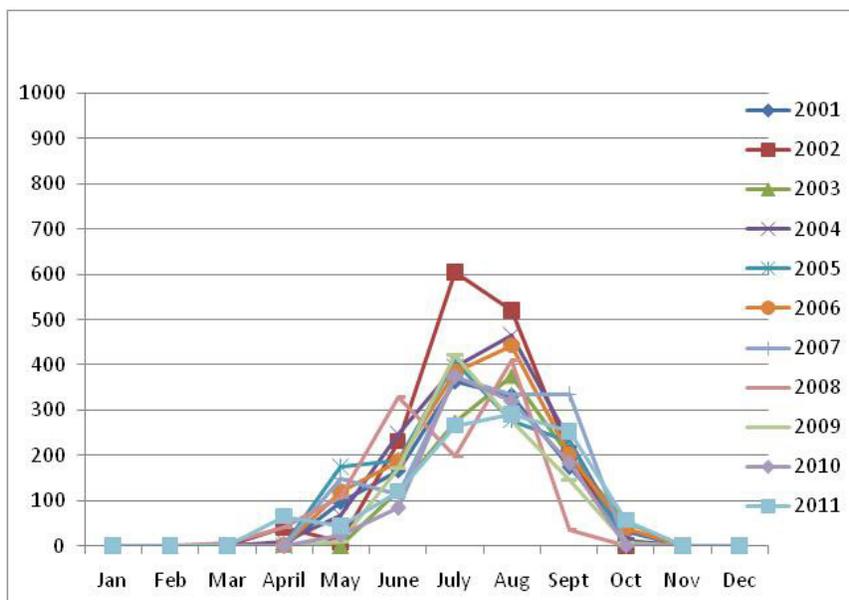


Figure 2 Mean Annual Rainfall 2001-2011 for the Study Area
 Source: NIMET / Field Work 2013.

removed in erosion (Kappel, 1996). Organic and chemical constituents of soil are also important and affect soil erodibility because of their influence on aggregate stability. Soil with less than 20% organic matter can be considered erodible (Morgan, 1979).

Climatic Factors

Rainfall is considered as one of the most important climatic factor, because it is the sole energy input into some of the process of erosion and gully development.

There must be a positive supply of running water for erosion to be effected. Rainfall alone could not be enough to cause erosion, as such the soil must be erodible. Figure 2 indicate the mean annual rainfall for the period of study. Kinetic energy of rainfall (E) is dependent on the amount of annual rainfall depth (R) and rainfall intensity. Average annual rainfall (R) for the study area calculated was 854.68 mm per year. Rainfall energy (E) calculated was 2114.074 J for the study area. The implication of this finding is that every year gully erosion increases due to rainfall intensity that produces rapid saturation of the soil, causing down cutting. These intense storms with mean of 25mm per hour on exposed surfaces such as the study area accelerate gullies. This finding agreed with Capra et al. (2009), who reported that a rainfall event is erosive if the height of rainfall is equal to or more than 13 mm per hour or the intensity in 15min is equal to or more than 6 mm. The implication of this finding is that every year gully erosion

increases due to exceeding rainfall threshold. However, this amount is high in an urban environment with increasing sealing surfaces. This finding agreed with Ologe (1987), who found out those stations with mean annual rainfall of 762mm to 1524mm lies within the maximum fluvial erosion.

Slope

The slope angle and slope length exerted a great influence on the degree of erosion in some location, more importantly around Rimin kebe and Gayawa were the slope is a little bit longer and steeper which influences the velocity of running water and runoff which affect the stability of soil. There are steeper slope in some site which range between 0.1° to 20° slope angles likewise some slope length is more than 500 metre. However, slopes constitute one of the most important factors of soil erosion, as the steeper the slope, the faster the runoff and the more intense the detachments. The slope length indicates the gravity of low infiltration and high runoff conditions. The implication of this finding is that Metropolitan Kano is dominated by active gully erosion and there is the need for holistic approach to watershed management. Ordinarily under vegetal cover, this slope gradient should not have enhanced erosion processes but due to exposure to direct raindrop impact, human activities and coupled with the poor soil aggregate has accelerated gully erosion. Areas having higher slope gradients showed greater responses to

Table 1: Mean Values of Gullies at Tsamiyar Matasa

| Station | slope angle (Sa) ⁰ | slope length (Sl) in (m) | gully depth (Dg) (m) | upper gully width (m) | surface area (m ²) | volume (m ³) |
|--------------|-------------------------------|--------------------------|----------------------|-----------------------|--------------------------------|--------------------------|
| A | 1.51 | 340 | 2.75 | 7.25 | 2466 | 6795.2 |
| B | 0.93 | 240 | 2.52 | 12.71 | 3064 | 7544.8 |
| C | 1.86 | 240 | 2.94 | 7.53 | 1806 | 5125 |
| D | 1.26 | 280 | 5.28 | 3.26 | 1340 | 5808 |
| E | 1.29 | 280 | 1.84 | 14.14 | 3960 | 7565 |
| Total | 6.85 | 1380 | 15.33 | 44.89 | 12636 | 32838 |
| Mean | 1.37 | 276 | 3.06 | 8.97 | 2527.2 | 6567.6 |
| SD | 0.31 | 36.66 | 1.17 | 3.95 | 924.59 | 965.41 |

Source: Field Work, 2013

decrease in gradient than those with lower slope gradients. Accordingly, for Rimin Kebe that has slope gradient of 13% and Tsamiyar Matasa with slope gradient of 2% the estimated soil loss was reduced by 29.28% and 15.13 % respectively for a 20% reduction in their slope gradients. This finding is in accordance with (Olofin, 2000), that Raindrop splash will move material further down steep slope than gentle ones, thus there is likely to be more runoff and its velocity will be faster. The amount of erosion therefore is not just proportional to steepness of slope, but rises rapidly with increasing angle.

Landuse/Cover factor

An estimated average of five trees per hectare was recorded by forestry staff (research assistance) within the study areas using Quadra. The difference in density is more in ground cover; as such more intense erosion was quantified in areas of absence of vegetation cover than in areas with little vegetation cover. The height of vegetation affects the kinetic energy load of rain drops reaching the ground surface, thus the higher the vegetation the lower the kinetic energy loads of raindrop and their erosive power. Meanwhile, the more the amount of vegetation cover, the more it cushions rain drop impacts and reduce runoff speed and the inverse is the case in the study area due to inadequate vegetation cover. The land covers factor range between 0.02 - 0.4. The activities of man in the study area has played a great role in the environmental destruction directly or indirectly through various activities in order to satisfy his need which in turn paves way to erosion hazard. This is inform of road construction and footpath the vegetation cover is removed and there is cutting and falling along the road, thereby creating a deep gullies. The animals trample trails and graze the vegetation along north eastern bypass. It is observe that trails are eroded and

develop into gullies. Farming practice in the area is mostly without conservation measure. Most of the time farmers cleared up little vegetation available in the area through bush burning the remaining trees are removed as source of fuel. This farming practice lead to accelerated erosion in the area.

In Tsamiyar matasa and Rimin kebe observation showed that heavy and articulated vehicles are moving around the area constantly for transporting the excavated sand and gravel for construction purposes. The building structures are mostly un planned types, popularly termed in Hausa as "Awon Igiya", mostly found around Gayawa, Rimin Kebe, Walalmbe, Wuro Bagga, Kureke, Tudun Murtala and kwana hudu among others, in which the houses are constructed without proper planning of road and drainage system. The processes allow the concentrated runoff to fallow any available routes. These activities make the soil to be losing its structure which in turn makes it vulnerable to accelerated erosion. This finding is in close relation with Khera *et al* (1998) studied effect of land cover and field slope on runoff and soil loss on loamy sand soil with 2 to 4% land slope and 6 crops cover treatment it was concluded that crop cover treatment significantly reduced both runoff and soil loss. Both were higher under higher field slope value.

Gullies Dimension

The dimension of gullies (coded A – O) are presented in tables to depict the nature and enhance finding about the level of erosion hazard base on the spatial distribution of gullies using field assessment inform of ground thruthing. Gully "A" is the second widest gullies measured. The mean slope angle (S.A) along it 1.5 degrees and the total slope length is 340 metres. The gully depth (G.D.) reading started from 0.4 to 7.2metres also the gully upper

Table 2: Mean Values of Gullies in Rimin Kebe

| Station | Slope angle (sa) ⁰ | Slope length (sl) in (m) | Gully depth (dg) (m) | Upper gully width (m) | Surface area (m ²) | Volume (m ³) |
|--------------|-------------------------------|--------------------------|----------------------|-----------------------|--------------------------------|--------------------------|
| F | 1.32 | 280 | 1.74 | 6.36 | 1777 | 3454.8 |
| G | 1.86 | 260 | 3.1 | 7.6 | 3140 | 6435 |
| H | 1.7 | 360 | 4.65 | 8.97 | 3226 | 15523.2 |
| I | 1.31 | 280 | 2.09 | 14.4 | 4036 | 7068.2 |
| J | 2.23 | 200 | 3.08 | 13.63 | 2726 | 8170.2 |
| Total | 8.42 | 1380 | 14.66 | 50.9 | 14905 | 40651.4 |
| Mean | 1.68 | 276 | 2.93 | 10.18 | 2981 | 8130.28 |
| SD | 0.34 | 51.22 | 1.01 | 3.25 | 736.6 | 4012.3 |

Table 3: Mean Value of Gullies Dimensions North Eastern Bypass

| Station | Slope angle (sa) ⁰ | Slope length (sl) in (m) | Gully depth (dg) (m) | Upper gully width (m) | Surface area (m ²) | Volume (m ³) |
|--------------|-------------------------------|--------------------------|----------------------|-----------------------|--------------------------------|--------------------------|
| K | 1.65 | 480 | 3.85 | 12.03 | 5763 | 17431.8 |
| L | 1.33 | 200 | 3.05 | 10.3 | 2058 | 5942.6 |
| M | 1.52 | 280 | 2.73 | 8.34 | 2708 | 10463.7 |
| N | 1.43 | 160 | 2.78 | 8.69 | 1390 | 4551.6 |
| O | 1.88 | 400 | 4.61 | 9.1 | 3455 | 18897 |
| Total | 7.81 | 1520 | 17.02 | 14.52 | 15374 | 57286.7 |
| Mean | 1.56 | 304 | 3.41 | 9.71 | 3074.8 | 11457.4 |
| SD | 0.19 | 120.26 | 0.73 | 1.34 | 1508.5 | 5833.2 |

Source: Field Work, 2013

width (W.G) range between 4.2 to 12.0metres. The total area occupied by gully (A) is 2466m², the advancement rate of gully heads was 4m per year and the total volume of materials removed was 6795.2m³. The vegetation is dispersed and scattered within the gully and field observation as well as the laboratory analysis shows that the types of soil that is dominant in the gully is sandy loam type of soil.

Estimated Soil Loss

It was estimated as shown in Table 4. That total surface area occupied by gullies from the study area stood at 42,915m² and the mean total volumes of material removed also represent the mean total volume of material loss for the study area is 130,776.1m³ for the period of study.

Gullies heads registered remarkable retreat head ward, the mean advancement rate is over 5.6 m/year. Rate of retreat depends largely on the instability factors operating at each head. Gully head H, O and K registered maximum headward retreat due to more height and gradient. The

process is associated with the energy generated by water falling over the headcut and flowing down the channel. If the energy of the flowing water is concentrated at the gully headcut, large masses of soil will be eroded.

The mean total volume of material removed from the mean gullies represent the mean volume of material for the whole gullies was 130,776.1m³ as a soil lost from gullies estimate in the study area, that resulted to the destruction of so many plot of land, farm land, houses and cemeteries which put so many residents at risk. Eventually, some gullies in (Rimin Kebe) are no go area especially early morning and late evening hours due to hoodlums and men of the underworld activities. This is in agreement with Patrick (1987), Kurar and Jung (1961), Boodel *et al* (1978), Kappel (1996) and Horton *et al* (1996) who developed a scheme to classify water erosion hazard severity from visible erosion feature base on the distribution and intensify of erosion damage. Equally, Kappel and Horton, *et al*, (1996) use the procedures of measurement of gullies in assessing erosion hazard classification. PlaMental, (1985) stated that, average

Table 4: Estimated Mean Volume of Soil Lost to Erosion in the Study Area

| Station | Surface area (m ²) | Volume of soil (m ³) |
|-----------------------|--------------------------------|----------------------------------|
| Tsamiyar | 12,636 | 32,838 |
| Matasa | | |
| Rimin kebe | 14,905 | 40,651.4 |
| North-eastern by pass | 15,374 | 52,286.7 |
| Total | 42,915 | 130,776.1 |
| Average | 14,305 | 43,592.03 |

Source: Field Work, 2013

erosion rate in India was 25 – 30 tones/ha/per year and about 40 – 1000 tones descend. Evans and Cooke (1986) stated that, In the Late 1970's and early 1980's there was a sharp rise in the number of recorded cases of erosion in Britain.

CONCLUSIONS

Kano metropolis is facing severe problem of gully erosion causing untold hardships and depression on the lives of the people. Complex interdependent mechanisms between rainfall characteristics, soil erodibility, land use, topography has reduced infiltration, which caused a higher surface runoff. This has increased deep cutting, take up valuable land, raised the cost of building and sinking of well water This chain of cause and effect hits most of the low income groups of the community, where the population density is highest and where the worst damages of gully erosion are found.

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APPENDIX I

Table 5: Result of Soil Analysis of Tsamiyar Matasa

| SAMPLES | COORDINATE | CLAY % | SILT % | SAND % | TEXTURE |
|---------|-----------------------------|--------|--------|--------|------------|
| A. | N 11.98365° E 008.60386° | 3 | 16 | 81 | SAND LOAM |
| B. | 11.98447° 008.60391° | 6 | 3 | 91 | SAND |
| C. | 11.98519° 008.60392° | 0 | 8 | 92 | SAND |
| D. | 11.98479° 008.60474° | 0 | 10 | 90 | SAND |
| E. | 11.98425° 008.60506° | 0 | 14 | 86 | SAND LOAM |
| F. | 11.99132° 008.60377° | 2 | 12 | 86 | SAND LOAM |
| G. | 11.98973° 008.60453° | 0 | 18 | 82 | SAND LOAM |
| H. | 11.98913° 008.60466° | 0 | 16 | 84 | SAND LOAM |
| I. | 11.98616° 008.60531° | 0 | 10 | 90 | SAND |
| J. | 11.98612° 008.60348° | 0 | 20 | 80 | SANDY LOAM |
| K. | 11.98898° 008.60250° | 0 | 18 | 82 | SANDYLOAM |
| L. | 11.98816° 008.60272° | 0 | 10 | 90 | SAND |
| M. | 11.99058° 008.60171° | 2 | 19 | 79 | SAND LOAM |
| N. | 11.99166° 008.60199° | 1 | 14 | 85 | SAND |
| O. | 11.99358° 008.60101° | 0 | 20 | 80 | SANDLOAM |

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Table 5: Continue

| | | | | | |
|----------------|-------------------------|------|------|-------|------------|
| P. | 11.99710° 008.60209° | 0 | 16 | 84 | SAND LOAM |
| Q. | 11.99495° 008.60264° | 2 | 16 | 82 | SAND LOAM |
| R. | 11.99413° 008.60285° | 4 | 10 | 86 | SAND LOAM |
| S. | 11.99262° 008.60310° | 0 | 16 | 84 | SAND |
| AVERAGE | | 10.5 | 14.0 | 74.14 | SANDY LOAM |

Source: Field Work, 2013

Table 6: Result of Soil Analysis along North Eastern Bypass

| SAMPLES | COORDINATE | CLAY % | SILT % | SAND % | TEXTURE |
|----------------|-----------------------------|---------------|---------------|---------------|----------------|
| A. | N 11.91589° E 008.53874° | 0 | 12 | 88 | SAND |
| B. | 11.91586° 008.53933° | 0 | 8 | 92 | SAND |
| C. | 11.91605° 008.53940° | 0 | 8 | 92 | SAND |
| D. | 11.91625° 008.53883° | 10 | 0 | 90 | SAND |
| E. | 11.91620° 008.53876° | 4 | 10 | 86 | SAND |
| F. | 11.91657° 008.53905° | 12 | 2 | 86 | SAND |
| G. | 11.91674° 008.53902° | 0 | 4 | 96 | SAND |
| H. | 11.91664° 008.53864° | 4 | 12 | 84 | SAND/LOAM |
| I. | 11.91640° 008.53838° | 12 | 0 | 88 | SAND/LOAM |

Table 6: Continue

| | | | | | |
|----------------|-------------------------|----|----|-----|-----------|
| J. | 11.91637° 008.53862° | 6 | 4 | 90 | SAND |
| K. | 11.91602° 008.53797° | 18 | 02 | 80 | SAND/LOAM |
| L. | 11.90871° 008.54968° | 0 | 6 | 94 | SAND |
| M. | 11.90860° 008.54976° | 14 | 6 | 80 | SAND/LOAM |
| N. | 11.90876° 008.54937° | 0 | 8 | 92 | SAND |
| O. | 11.90868° 008.54953° | 18 | 10 | 72 | SAND/LOAM |
| P. | 11.90859° 008.54965° | 0 | 10 | 90 | SAND |
| Q. | 11.90847° 008.54965° | 0 | 0 | 100 | SAND |
| AVERAGE | - | 11 | 16 | 73 | SAND |

Source: field work Fie 2013,

Table 7: Rimin Kebe Erosion Site Result of Soil Analysis

| SAMPLES | COORDINATE | CLAY % | SILT % | SAND % | TEXTURE |
|---------|-----------------------------|--------|--------|--------|------------|
| A. | N 12.04671° E 008.55859° | 0 | 12 | 88 | SAND |
| B. | 12.03984° 008.55840° | 0 | 8 | 92 | SAND |
| C. | 12.03971° 008.55838° | 0 | 8 | 92 | SAND |
| D. | 12.04063° 008.55931° | 0 | 10 | 90 | SAND |
| E. | 12.04076° 008.55956° | 0 | 0 | 100 | SAND |
| F. | 12.04136° 008.56058° | 10 | 10 | 80 | SAND |
| G. | 12.04207° 008.56171° | 4 | 10 | 86 | SAND |
| H. | 12.04224° 008.56205° | 2 | 12 | 86 | SAND |
| I. | 12.04221° 008.56194° | 0 | 4 | 96 | SAND |
| J. | 12.04196° 008.56170° | 4 | 12 | 84 | LOAMY SAND |
| K. | 12.04163° 008.56141° | 2 | 4 | 94 | SAND |
| L. | 12.04065° 008.56088° | 0 | 6 | 94 | SAND |
| M. | 12.04037° 008.56011° | 0 | 6 | 94 | SAND |
| N. | 12.04052° 008.55962° | 0 | 10 | 90 | SAND |
| O. | 12.03762° 008.56151° | 10 | 20 | 70 | SANDY LOAM |
| P. | 12.03746° 008.56177° | 0 | 6 | 94 | SAND |

Table 7: Continue

| | | | | | |
|----------------|-------------------------|------|------|------|------------|
| Q. | 12.03767° 008.56220° | 0 | 8 | 92 | SAND |
| R. | 12.03784° 008.56242° | 0 | 8 | 92 | SAND |
| S. | 12.03758° 008.56233° | 0 | 16 | 84 | LOAMY SAND |
| T. | 12.03716° 008.56220° | 2 | 14 | 84 | LOAMY SAND |
| U. | 12.03679° 008.56195° | 2 | 14 | 84 | LOAMY SAND |
| AVERAGE | | 11.4 | 14.3 | 73.2 | SANDY |

Source: Field Work, 2013