GULLY DEVELOPMENT ALONG RIVER NGADDABUL FLOODPLAIN OF MAIDUGURI, BORNO STATE, NIGERIA

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ABSTRACT

This study focused on gully development along River Ngaddabul floodplain in Maiduguri, Borno State, Nigeria. The objectives were to examine the factors and processes influencing gully development. The data used were obtained through measurements of the parameters such as gully length, width and depth at four locations. Also examine were slope angles, relief and vegetation of the topography and mapping of the gully patterns. The data were subjected to laboratory and statistical analysis. The findings revealed that factors that influence gullying (process) along the floodplain are rainfall amount, runoff taking advantage of footpaths, wheeled-tracks and soil texture. It was also revealed that human activities such as sand mining contribute to gullying processes by influencing mass wasting processes like slumping through undermining of channel banks leading to caving as well as collapse of channels. The construction of new houses along the road due to population pressure accelerated the gullying processes. The River Ngaddabul annual floods also contribute towards gullying (processes) by deepening the channels, leading to the initiation of new gullies on the slopes. In view of these, the study recommended that drainage channel should be constructed in the gully affected areas to check the volume of runoff influencing gullying. Sand quarrying should be restricted to specific locations along the road in order to prevent further disfiguring of the Ngaddabul channel through undermining processes along the channel.

***Keywords:** Floodplain,Runoff, Gully erosion, Gully pattern, Maiduguri.*

INTRODUCTION

Erosion is a process in which soil is bodily displaced faster than it can form (Igbokwe, 2008). Soil erosion in form of gully is a striking feature on the land surface and also an important agricultural problem in the world. Cooke and Doornkamp (1974) identify two forms of erosions, geological and accelerated soil erosions. Geological erosion is the rate at which land would be normally eroded in a gradual manner. While accelerated erosion occurs when man alters the natural system by various land use practices such as deforestation, cultivation, overgrazing, bush burning, and quarrying. Such activities accelerate soil erosion. However, land that is used for the production of agricultural crops generally experiences a significantly greater rate of erosion than that of land under natural condition. As such, geological erosion is rapidly paving way to accelerated erosion mainly due to human's interference in the ecosystem through various land use practices. Hence, it falls squarely into the subject of environmental management. The problem of soil erosion is really the problem of accelerated erosion. In Nigeria, many areas experience soil erosion especially the southeastern part of the country because the soils are sandy and usually have low organic matter status. The area also experiences rainfall of high intensities and long duration (Ofomata, 1964). According to Fubara (1986), over 860,000 hectares of land in Nigeria are badly affected annually and this implies that the nation loses the daily carbohydrate need of about 21,250,000 tonnes due to erosion. Thus, two broad types of soil erosion in the Nigerian savanna have been identified by Ologe, (1973). These are wind and fluvial erosions. Ologe (1972) further laments that the later create sheet, rill and gully erosions, which are readily observable in the field. Sheet erosion occurs where runoff is not concentrated but rather flows as a thin sheet over the entire surface or over a good proportion of that surface. Rill erosion is innumerable, closely spaced channels scored into the soil. Gullies develop where runoff is concentrated along definite channels and grow lengthwise by head ward erosion (or head scarp retreat) and sideways by basal sapping.

Various aspects of accelerated erosion particularly, gully erosion, has been studied all over Nigeria (Grove, and Pullan 1963, Ofomata, 1965, 1966, and 1978, Lal, 1981, Jeje and Agu, 1990, Olofin, 1986, Floyd, 1965, Ogbukagbu, 1976, Okagbue and Uma, 1987, Ofomata, 1978). Common to most of these studies are observations that gullying in Nigeria is caused by human activities, geological set up, ground water conditions and soil characteristics. Some studies have been conducted on gullying processes in the Sahel bioclimatic zone of Nigeria, particularly on the gullies within and around Maiduguri metropolis, attributing gullying processes to soil characteristics; coalesce of rills into gullies along River Ngaddabul (Nwaka and Bababe, 1989, Nyanganji, 1994). The impact of land use on gully formation in Nigeria has not been well documented. Therefore this study is conducted to address the issue of gully development along river Ngaddabul floodplain of Maiduguri, Borno State, Nigeria.

STUDY AREA AND THE METHOD

Maiduguri, the capital of Borno State, lies between latitudes 11^0 45'N and 11^0 51'N longitudes 13^0 2'E and 13^0 9'E. It is located in the Ngadda Basin, a seasonal stream that flows through Maiduguri. However, the town Maiduguri, according to population census of 2006, has a total population of 540,016 (NPC, 2007). Most of the people living along the floodplain are peasant farmers. Land use at the site is characterized by permanent rain fed cultivation of grain crops such as sorghum and millet. Dry season Fadama (Market gardening) cultivation is practiced at some points, using Shaduf irrigation system. Also cultivations are usually carried out right to the edge of gullies. Other land use activities include sand mining, grazing, urban house construction, garden and orchards. The climate of Maiduguri is generally semi-arid, with moderate variations in temperatures; the mean monthly minimum temperature is lowest (13.5^{o}C) during the period of strongest and most constant northeast winds (Harmattan) in December and January; and highest (24.7^{o}C) in April. The mean monthly maximum temperature is highest (40.2^{o}C) prior to and during the onset of the rains in April and the lowest (31.3^{o}C) during the peak rained period of August

(NIMET, 2009).The geology of Maiduguri comprise sedimentary rocks which fall under Chad formation, is made up mainly of argillaceous but well defined sandy horizons (Kogbe, 1989).Sand deposits are angular and of drifted fluvial origin. In many areas, the clay became very dark as a result of the accumulation of organic matter and is then referred to the as the Firki (black cotton soil). Where exposed at the surface, the clays become plastic and saturated with water during the rainy season, when it is converted into swamps from which numerous small streams developed (Udo, 1981). It is slightly some 320m above mean sea level (Nigeria Data Bank 2006). In Maiduguri, the prominent relief feature is the Bama Beach Ridge (BBR) which rises to spot height of 338m above mean sea level west of university of Maiduguri (Nyanganji, 1994). The surfaces are covered by thick heterogeneous alluvial sand deposit with occasional alluvial sand deposits of degraded and remnant of sand dunes (Nwaka and Bababe, 1989).The soil is porous and contains a lot of air spaces with high alkaline content (Maxlock Group, 1979). The River Ngaddabul is one of the two major rivers flowing through the metropolis. It flows northward from its source in southern hills of Damboa. It has a characteristic of over bank spillage (Nyanganji, 1994). Occasional upsurge of the river brings erosion hazards to the metropolis (Nwaka and Bababe, 1989). The river water disappear into the Jere Bowl of Lake Chad, about 70miles (118km) northeast (Encyclopedia Britannica, 2006).

The four active gully heads in the units mentioned above were the target population. These units were chosen mainly because of the serious erosion degradation threat posed by the active gully heads in the area.The study sites started from the bridge beside Kyarimi park (Zoo) passing through Moduganari, Shuwari, Kafanti and Zannari respectively up to Dala Shuwari the southern end along the river Ngaddabul. Four prominent gullies were at Kafanti, Zannari, Shuwari and Moduganari respectively. Also, four soil sample pits, one from each of the gully sites were dug and soil samples were collected.

The data for this study were obtained through measurement of the prominent gullies length, width, depth and slopes of surrounding areas. The floodplain with a length of about 6km long was purposely divided into 4 portions. Each of the portions is 1.5km long. Since the research wants to map the gully affected areas, the area was delineated so that observations are restricted to the areas of prominent gullies within the sample frame, that is, in the western side of the floodplain. As such, the four prominent gullies seen during the reconnaissance visit were surveyed and mapped. Although, there are numerous rills and gullies in formations, but only the prominent ones are being considered. The measurements were done at two different periods. First was before the rainy season in March and the second measurement was during the peak period of the rain in August. The instruments used are measuring tape, ranging poles and Abney level. Soil samples were air-dried in the laboratory, ground and sieved through a 2mm sieve to remove materials greater than 2mm. The less than 2mm portion was used for the analysis. Fieldwork was performed and morphological characteristics were described using guideline contained in the Soil Survey Manual (Soil Survey Division Staff, 1993) . The Bouyocous hydrometer method as described by Gee and Bauder (1986) was employed and hydrogen peroxide to destroy the organic matter while sodium hexametaphosphate (Calgon) used as dispersant to obtain percentage sand, silt and clay. Soil aggregate stability was determined by the procedure of Kemper and Chepil (1965) as modified by Mbagwu et al, (1994). The soil structure, drainage condition and slope were determined in the field following the procedure in the field in the USDA Soil Survey Manual (Soil Survey Division Staff, 1993).

RESULTS AND DISCUSSION

Morphometric of the prominent gullies at the four locations after the initial measurement in August 2008: The analyses of data collected in the field through measurement of the gully morphological variables like length, depth, width, slopes and processes are presented below. The gullies were measured at two different periods. First they were measured and mapped before the onset of the rain in March and later another measurement was also taken after the peak rain in August. Four prominent gullies were identified. These are Kafanti, Zannari, Shuwari and Moduganari gullies respectively. From the results obtained by physical assessment of the prominent gully catchments, two types of the gully forms were identified. These are first order gullies as in Shuwari and Moduganari gullies and second order gullies at Kafanti and Zannari gullies. The gullies at Kafanti and Zannari exhibited 2nd order gullies. The gullies here are incising in a gently sloping valley (Plate 1), with generally well-defined, somewhat irregular margins due to the existence of numerous small lateral head cuts. While, Shuwari and Moduganari gullies displayed remarkably 1st order gullies (Fig 4).

The findings also reveal that both physical and human factors played important roles in influencing gully erosions. Also the main gullying processes examined ranged from mechanisms of undermining, collapsing, and carving of the gully channels. However, rills also developed on the adjacent plains of the river banks which discharged runoff to the main gullies taking advantage of slopes and gravity and end its water to Ngaddabul River. The gullies are more in the western side of the Ngaddabul river bank showing the influence of the settlements (Fig 4.2). The morphometric of the gullies in most locations shows evidence of recent incision into the mottled weathering horizon. The gullies are very wide where they cut across the surface sandy soil, becoming narrower where incised into the clayed mottled zone. The narrow 1st order channels which are near vertical to overhanging are usually asymmetrical with the slip-off slopes facing near perpendicular slopes. The first order gullies around Kafanti and Zannari gully sites are all seen to develop on footpaths, while the 2nd order segments have developed along former unpaved drainage channels where sheet flow, rills and the 1st order gullies converge. The figure 4.2 shows the main gully channel which served as the subsequent basin at Kafanti and Zannari areas, while the two other minor gullies connected to the main gully channel at the western side are the consequent basins which made the morphometric of the 2nd order gully.

The gullies here are incising in a gently sloping valley with general well-defined, somewhat irregular margins due to the existence of numerous small lateral head cuts. The gully slopes in rectilinear and inclined at 30 - 40 in all the locations except at Shuwari gully area where it is up to 70. Even though, gullying is expected to be characteristic of steeper slopes, it is known, however, that gullying also takes place on such gentle and is even more common on such gentle slope from 3^o-5^o as in case at most of the locations during the field checks, than on every steep ones. Field observation showed in Moduganari and Shuwari areas gully system, the bulk of surface runoff that incising the gullies in the area was generated about 200m away from the gully site. This finding upholds Olofin (1978) assertion that the characteristics of the main channel including its steep bank constitute the primary factor that kicks start gullying in the savanna. In fact, the runoff at Shuwari gully area originated right from the tarred ring road near Maiduguri International Hotel about 300m away, which mplies the runoff was generated in a distant from the gully point. The active gully here is therefore, related to road construction. The area has a general elevation of about 320m above mean level (Maid sheet 90 NW) but the ground slope is imperceptibly in a Northwest - Southeast direction as evidenced by the flow of the gully systems into the Ngaddabul river. These gullies, ordinarily under vegetal cover, slope gradients should not enhance erosion processes but due to exposure to direct impact of raindrop coupled with activities of man, accelerated erosion become pronounced in all the gully erosion areas.

Rainfall as a factor influencing gullying processes: The total annual rainfall for Maiduguri from 2003 - 2008 measures between 533 - 897mm. Greater percentage of the stated amount falls between May to September and at the onset of the rainy season, the scanty vegetal cover offers less protection to the soil. Rainstorm induces flash runoff leading to erosion. Cocheme and Fran quip (1967) opine that wherever mean annual rainfall exceeded 500mm, even in the Sahel zone where annual rainfall is low, considerable runoff can occur. When the runoff occurs in an area cleared of vegetation and exposed surfaces, as in most of the locations in the gully sites. Such intense storms can affect near surface mechanical eluviations, leading to the blocking of pores spaces, and reduction in infiltration rate. Hence, the gullies are formed by surface runoff from localized rainfall events of high intensity in the fine to coarse grained particles. Egboka (2004) further states that gullies occur where spring issues from permeable sands come into contact with less permeable deposits beneath. The new extension of the gully channel has cuts off the footpath linking mobile police barracks and the police headquarters (Fig 1).

Moreover, the rainfall intensity at the period of the study in 2008 also posed serious threat to buildings at the mobile police barracks and even some outside the barracks fence. The gullying processes had force some boys' quarters to be abandoned. And many buildings outside the barracks fence were at the verge of collapsing into the channels. The gullies in Kafanti and Zannari areas have been observed to be initiated by rainfall intensity on surfaces whose vegetation cover has been removed for the establishment of the new houses and sites of uneven compaction of surface soils by human and animal feet, wheeled traffic, in off-road locations. However, the gradual processes of gullying mechanisms were triggered by the construction of new estate particularly at Kafanti and Zannari areas. The results on table 1 corroborate Mbagwu *et al* (1994) assertion that soil aggregate of the soil is determined by its stability. In this study, it would be premature to formulate a general model on the development of gullies along River Ngaddabul floodplain, Maiduguri Metropolis.

Table 1: Results of the Soil Texture, Structure and Aggregate Stability for the studied gullies

Sample sites	HD (cm)	Textural class	Particle size distribution %Sand	%Silt	%Clay	Structure
Kafanti gully	0-20	Sandyloam (Sl)	69.40	18.50	12.10	Sub-angular blocky
Zannari gully	0-20	Sandyloam (Sl)	54.40	25.00	21.60	Fine granular Shuwari gully
	0-20	Sandyloam (Sl)	61.90	15.60	22.50	Fine Subangar blocky
Moduganari gully	0-20	Loamsand Ls	51.90	20.60	27.50	Fine-medium Sub angular blocky.

Source: Fieldwork, 2008. HD = Horizon and Depth

Nevertheless, the study has shown that there are interesting possibilities for further research on these gullies, particularly in terms of evaluating hypothesis on episodic erosion and rates of gully growth. This preliminary survey has also provided some useful information concerning the distribution, morphology and enlargement of gullies in this part of River Ngaddabul, Maiduguri. However, mapping of the gullies shows that these features are restricted almost entirely to the western side of the road. This appears to be related to settlement influence. The study highlights the importance of all the factors that affects soil erosion such as high rainfall amount ranging from 300mm - 750mm with its intensity , high proportions of sandy soil ranged between 51% - 69% in the four locations, in which the soil belongs to 'irrigable" class of the Modified US Bureau of Reclamation Land Suitability Class specifications (FAO, 1976, Adepetu et al., 2000).

Also, slopes of varying degrees ranging from 3% - 7% and sparse vegetation. The sparseness of vegetation in the area may be due to the seasonality of rainfall and some human activities in falling trees. However, in most of the locations visited within the study area, man is to blamed mostly on socio-economic related. especially, lack of drainage channels, poor urban planning, and cultivation of arable lands up to the edge of river banks, activities of sand quarrying as well as excavations acting simultaneously to aggravate gully processes in the area, with the physical factors that greatly contributed to the development of gullies. One other thing is the unfortunate location of Maiduguri urban centre in the catchments of actively incising channel of Ngaddabul river floodplain with its seasonal floods and inundation that has been a factor responsible for accelerated erosion in the area, it processes and their operational mechanisms must be properly understood before any meaningful measures of control can be undertaken.

CONCLUSION AND RECOMMENDATIONS

The aim of this study was to assess gully erosion along River Ngaddabul floodplain within Maiduguri Metropolis. To achieve this aim, mapping of the gullies in the affected areas; examining the factors influencing gully erosion, descriptions of the morphology of the gullies were also explored. Nonetheless, based on the findings of this study, it will be concluded that unsustainable development is largely responsible for gully formation in the study area. Hence, the reclamation of the gullied land should normally follow the recommended conservation and control measure. The gullies that run-down to the river banks require mechanical protection by way of erecting permanent concrete structures, which will check slumping and carving-in through inception. Built-up areas around and close to the main road should be provided with concrete drainage channels which can effectively collect increased raindrops from galvanized house roofs. Socio-economic activities other than agriculture, such as excavation of earth and bricks-making which aggravated the erosion processes should be confined to specific locations rather than dotted activities along the valley. Though solutions to control erosion have been suggested in order to produce a reliable schedule of conservation and control measures, a more comprehensive and detailed survey would need to carry out in these areas. It is hoped that further research here can include the use of aerial photography to facilitate accurate mapping of the sites and the erosion features. The result obtained will help in the detailed design of gully erosion control measures like checking dams, terraces as well as diversions. This study has however, highlighted erosion features along Ngaddabul river floodplain and these should be controlled by combined team of engineers, erosion specialists and local people supported by the State and local government authorities.

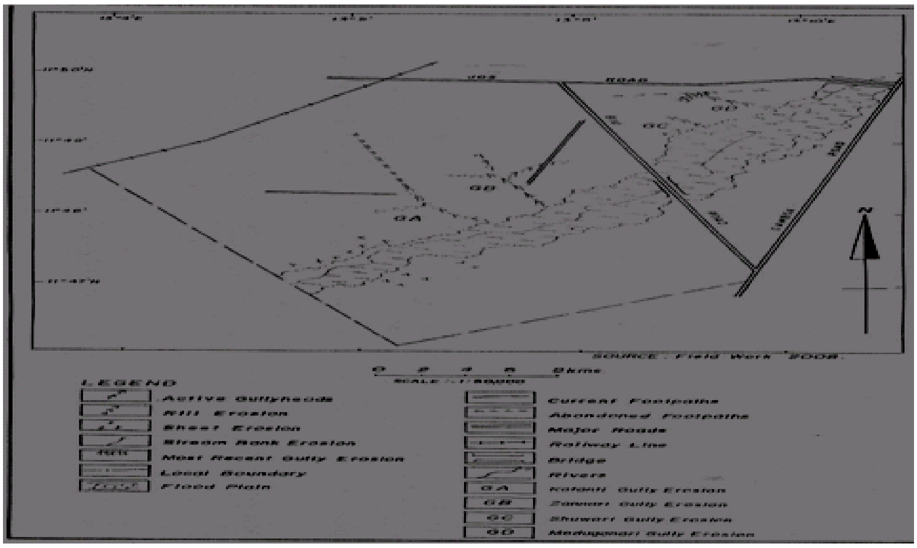

Fig. 1: Gully Structure along Ngaddabul River Flood Plain. ***Source:*** Fieldwork, 2008

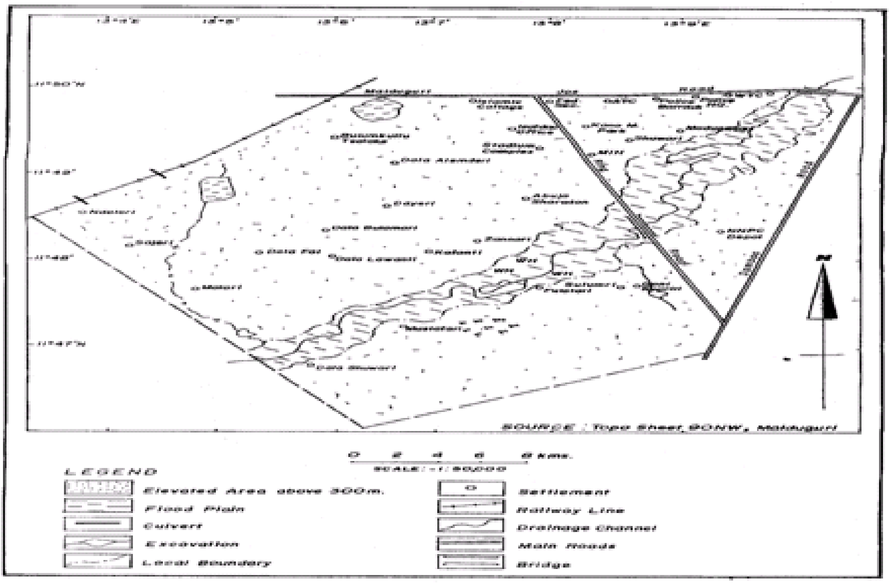

Fig. 2: Settlement distribution along Ngaddabul River Flood Plain.
Source: Topo Sheet, 90UW, Maiduguri

Plate 1: Cut off Road by Gully Erosion behind Mobile Police Barrack

Plate 2: Gullying Process due to Sliding and Caving in Shuwari

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