**Geological and Erodibility Investigations of Rafin Gora area of Niger State, Northern Nigeria**

**BY**

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**Abstract**

Geological, geotechnical and geochemical studies were carried out on rocks and soils of Rafi Gora area in order to ascertain the erodibility of the soils. Medium and coarse grained sandstone and clay stone were mapped with structures like joints, cross bedding (120/18E and azimuth of 190S), Herringbone, clay clasts, lamina and bioturbation. The sand content of the soils is between 59% and 90%, silt ranges from 18% to 1% and clay constitutes between 9.9% and 32%). The soils classified into sand (S), Loamy Sand (LM), Sandy Clay (SC) and Sandy Loamy using USDA textural classification. The pH value of the soil ranges from 4.31 to 6.5 and the Organic Matter (OM) is from 1.07 to 5.79%.This indicates that the soil in the whole area is slightly acidic and may require lime to buffer the acidity**.** The Coefficient of permeability, k is between 1.29 × 10-6 to 1.29 × 10-3 cm/sec which is classified to be moderately rapid(FAO, 2010), an indication of base flows which could result in the collapse of river bank and consequently advance the growth of gullies.Erodibility index (EI) ranges between 0.01 and 0.16Pearson’s correlation between soil properties and erodibility index shows a significant positive relationship between soil erodibility index with silt content (0.96), clay content (0.30) and organic matter content (0.20) but significant negative relationship with sand content, pH and permeability. It was advised that excavation of vulnerable claystone by the natives for building construction be totally discouraged.

**INTRODUCTION**

The causes of gully erosion with respect to the geologic settings as suggested by the earlier studies are numerous. Some of the identified natural causes include tectonic activities, uplift, climatic factors, geotechnical properties of soil, among others. Anthropogenic causes include farming and uncontrolled grazing practices, deforestation, and mining activities (Ezechi and Okagbue, 1989)

The greatest threat to the environmental settings in Nigeria is the gradual but constant dissection of the landscape by soil erosion. Gullies have assumed a different dimension such that settlements and scarce arable land are threatened (Igwe, 2003). Therefore, gully erosion problems have become a subject of discussion among soil scientists, geographers, geologists, engineers and social scientists.

Rafingora is located in Northern Nigeria where desertification and aridity had been the major environmental problems that has been receiving global attention. Emergence of gully erosion as deep as 12 m in the region has been reported by Gabriel and Jibril (2011), Mbaya *et al.* (2012) and Mahmud and Umaru (2018). In order to mitigate these gullies there is need for geological, geotechnical and chemical evaluation of the soil associated with gully.

Geologically**,** the area lies within the basal part of Bida Formation (Doko member). Much like its lateral equivalent (Lokoja Sandstone), the Bida Sandstone lies unconformably on the crystalline Basement complex and consists of a basal conglomerate with a succession of cross-bedded white to grey sandstones intercalated with kaolinitic clays believed to have been derived from nearby deeply weathered basement rocks (Rahaman *et al.,* 2019).

Ofomata(1981) indicated that areas of high susceptibility to gully erosion correspond to geological regions of weak unconsolidated sandy formations while least susceptible areas are within the consolidated tertiary to recent in areas they studied. Classical gullies are located in the False-bedded sandstone, Coastal Plain sands, Nanka Sands and the Bende-Ameki Formations of southeastern Nigeria. These are all sandy formations which have more gullies than their Shale formation counterparts. The geology therefore plays direct and indirect influence on the gully formation. The indirect effect is on the soil formation and the nature of soil which contribute significantly to erosion processes. Ezechi and Okagbue (1989) summarized the types of gully erosion with respect to their modes and conditions of formation and indicated that the nature of the underlying bed (or geology) has a bearing on the initiation and propagation of gullies.

The erodibility of the soil (K) is an estimate of the ability of soil to resist erosion based on the physical characteristics of each soil. Generally, soils with faster infiltration rates, higher levels of organic matter and improved structure have a greater resistance to erosion (Wall *et al.,* 1987) Sand, sandy loam and loam textured soils tend to be less erodible than silt, very fine sand, and certain clay textured soils (Wall *et al.,* 2003). Silt dominated soil were found by Bobe (2004) to be more susceptible to particle detachment in terms of sediment yield than sandy soil. This he attributed to relative transportability of fine and none aggregated silt particles.

Early studies by Bennett (1926), Middleton (1930) and Baver (1933) demonstrated that erosion rates were influenced by soil properties. Igwe (2005) remarked that a number of factors such as the physical and the chemical properties of the soil influence erodibility. Higher erodibility value (K-factor) indicates the soil’s higher susceptibility to soil erosion (Adornado *et al.,* 2009). Wischmeier and Smith (1978) and Renard *et al.* (1997) used an equation that relates textural information, organic matter, information about the soil structure, and profile permeability with the K factor or soil erodibility factor.

**THE STUDY AREA**

RafinGora is situated in Kontagora Local Government Area of Niger state and it lies within latitude of 10° 16̎ N to 10°27̎ N and longitude 5°23̎ E and 5°.26̎ E (Figure 1.1). The area of a linear settlement covers about 30km2 The area is accessed through major road that linked Mokwa to Kotongora that have been threatened by gully effects with foot paths linked to genesis of several rill gullies heads in the village.

The studied area has a total annual rainfall of about 1100-1332mm with the highest mean monthly rainfall is in August with about 240-300mm (Nigeria Metrological Agency, 2012). The highest monthly temperature is March with temperature of about 37˚C and the lowest temperature is recorded in the month of August with temperature of about 23˚C. The vegetation comprises of shrubs, grasses and tall trees that are easily identified in the dry season compare to the wet season (NIMET, 2012).

The area is characterized by long extensive ridges of hills and plain lands. The entire area has a good drainage networks cutting across the community that discharges into river Kontagora. The contour values range from 225 to 370 and most houses built closer to the drainages are exposed to gully effects. The vast and fertile land is mostly used for rice, millet, and beans farming except in few places where houses structures are built. Both the structures and farms becomes more exposed to gully erosion during every raining season.

METHODOLOGY

**Geology mapping and Soil sampling**:

The lithology of the area with various structures present was studied using metre rule to measure the thickness of the lithologies and geological compass to denote the strike, dip and azimuth of the structures (figure I). Eight soil samples were taking on across the gully profiles and used in determining the geotechnical and geochemical influence of soil on formation and expansion of gully erosions and other 15 points offsite using hand trowel for a depth 50cm to generate the erodibility map of the area.

Geotechnical investigation included sieve analysis, Attergerg limits and permeability using standard procedures (BS 1981, ASTM 1979) while the geochemical involved organic matter, pH and temperature carried out at the civil Engineering laboratory of the Federal University of Technology, Minna. D10 = grain size value at 10% passing, D30 = grain size value at 30% passing, D60 = grain size value at 60% passing was used to calculate Cc and Cu with the following formulae (equation 1 & 2)

Cu = ………………………………………………………1

Cc = ……………………………………………..2

**Erodibility index was Calculated based on** a multiple regression equation developed by David 1988 and adopted by Hernandez *et al.,* 2012.

K D = {(0:043 \* pH) + (.0:62 /OM) + (00082 \* S) – (0.0062 – C)} x Si

where pH= acidity of the soil; OM: organic matter (%); S: Sand content (%); C: clay ratio = (% clay / % sand + % silt); Si = Silt content = % silt/100

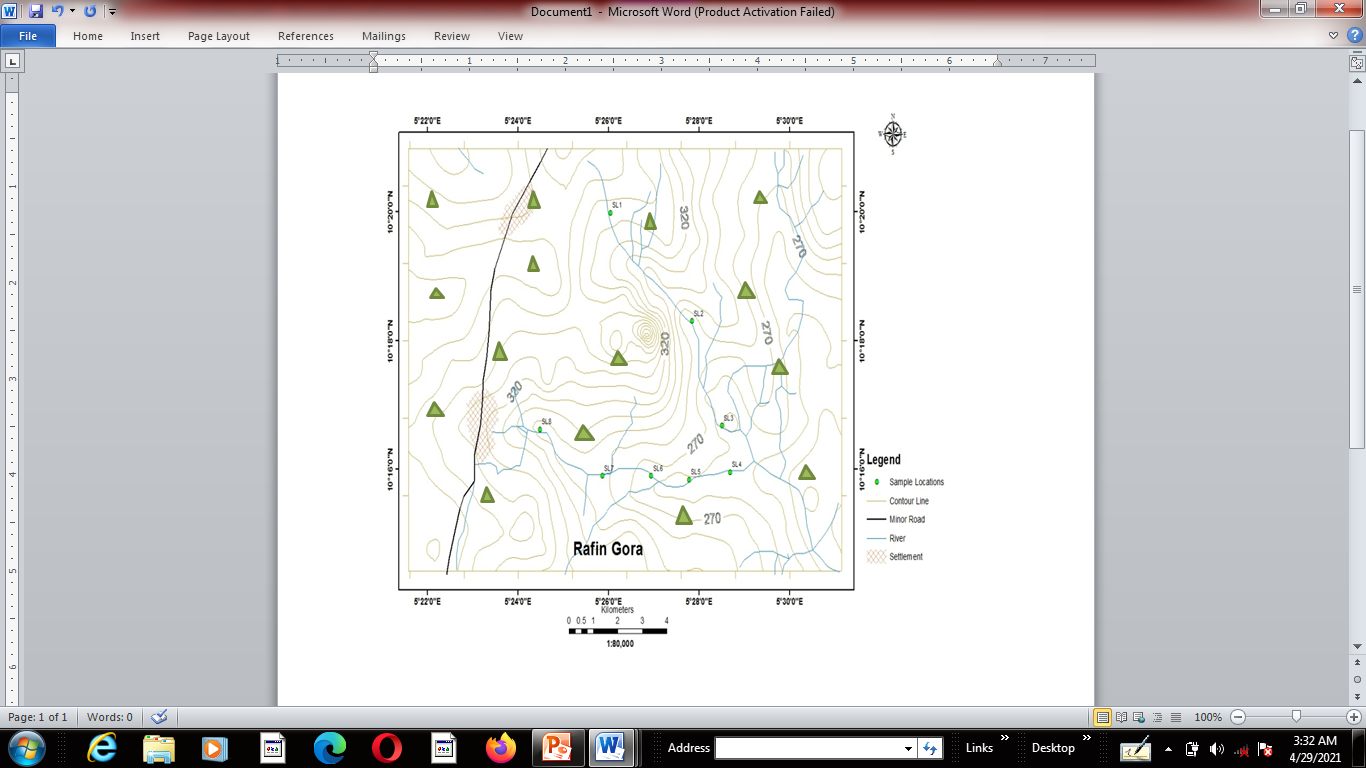


Figure 1: Sampling points across the gully profiles within the study area.

RESULTS AND DISCURSSION

The study area is underlain by reddish, poorly sorted sandstone. Three different lithologies were identified which included: Light reddish medium grain sandstone, Light brownish coarse grain sandstone and Yellowish clay stone. Geological structures like joint, cross bedding (120/18E and azimuth of 190S), Herringbones structures, Clay clast, lamina and Bioturbation were identified with their various implications in development of the gullies. The existence of the herringbones structure in Lokoja SST as lateral extension of Bida SST has been reported by Ojo and Akande in 2012 attributing it origin to tidal lag processes. Figure 2 is the Lithological section of the study area.

Figure 2: Lithological section of the study area

CampanianBidaSandstone

Doko Formation

B

122.2

3.2

Reddish,medium grain,arenitic sandstone

Herringbone cross bedded, Light brownish coarse grain, arkosic sandstone

Yellowyish claystone

7.2

C

A

**Table 1: Erodibility index of the study area**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Location** | **Longitude** | **Latitude** | **Sand** | **Silt** | **Clay** | **TC** | **OM** | **pH** | **Kcm/sec** | **EI** |
| L1 | 10 21 12 | 5 29 45 | 62 | 9 | 29 | SCL | 5.79 | 5.65 | 0.23 | 0.06 |
| L2 | 10 17 33 | 5 28 55 | 71 | 5 | 24 | SCL | 1.07 | 4.61 | 0.35 | 0.06 |
| L3 | 10 19 55 | 5 28 14 | 65 | 5 | 30 | SCL | 2.79 | 4.58 | 0.2 | 0.04 |
| L4 | 10 21 6 | 5 27 15 | 64 | 18 | 18 | SL | 3.21 | 4.31 | 0.78 | 0.16 |
| L5 | 10 16 45 | 5 27 32 | 61 | 11 | 28 | SCL | 4.71 | 4.39 | 0.25 | 0.09 |
| L6 | 10 19 33 | 5 26 1 | 70 | 4 | 26 | SCL | 2.14 | 4.07 | 0.3 | 0.04 |
| L7 | 10 20 42 | 5 22 52 | 81 | 8 | 11 | LS | 5.79 | 4.45 | 2.18 | 0.08 |
| L8 | 10 18 16 | 5 22 14 | 73 | 6 | 21 | SCL | 2.36 | 4.53 | 0.51 | 0.06 |
| L9 | 10 15 54 | 5 23 9 | 69 | 2 | 29 | SCL | 1.07 | 4.79 | 0.23 | 0.03 |
| L10 | 10 16 12 | 5 25 3 | 90 | 1 | 9.9 | S | 1.5 | 5.16 | 2.81 | 0.01 |
| L11 | 10 17 52 | 5 29 4 | 59 | 9 | 32 | SCL | 1.93 | 4.05 | 0.17 | 0.09 |
| L12 | 10 16 22 | 5 28 12 | 63 | 7 | 30 | SCL | 2.57 | 4.38 | 0.2 | 0.06 |
| L13 | 10 16 30 | 5 27 45 | 62 | 9 | 29 | SCL | 1.29 | 4.49 | 0.22 | 0.11 |
| L14 | 10 16 33 | 5 25 54 | 89 | 1 | 11 | LS | 3.64 | 4.96 | 2.33 | 0.01 |
| L15 | 10 16 34 | 5 23 45 | 90 | 1 | 9.9 | S | 1.71 | 6.5 | 2.81 | 0.01 |
|  |  | Mean | 71.2 | 6.40 | 22.52 |  | 2.77 | 4.73 | 0.90 | 0.06 |

Table 1 revealed that the sand content is between 90% in location 15 to 59% in location 11. Silt content ranges from 18% in location 4 to 1% in location 15 and Clay contents were observed to be highest in location 11(32%) and lowest in L15 ( 9.9%). The soils classified into Sand (S), Loamy Sand (LM), Sandy Clay (SC) and Sandy Loamy using USDA textural classification,

The pH value of the soil ranges from 4.31 in location 4 to 6.5 in location 15and the Organic Matter content (OM) was as well observed to be highest in location 1 at 5.79% and lowest at 1.07 in location 9 (table 1). This indicates that the soil in the whole area is slightly acidic and may require lime to buffer the acidity. And the permeability was observed to be highest in location 15 at 2.81cm/s and lowest in l3, L12 and L13 at 0.2cm/sec (table 1).The Coefficient of permeability, k is between 1.29 × 10-6 to 1.29 × 10-3 cm/sec which is classified to be moderately rapid (FAO, 2010), an indication of moderately rapid base flows which could result in the collapse of river bank and consequently advance the growth of gullies.

Table 1 further shows that the Erodibility index (EI) soil around location 4 and 13 both have high index value of 0.16 and 0.105 respectively while the least erodible index are recorded in L14 and L15 with index value of 0.01 respectively. Pearson’s correlation between soil properties and erodibility Index shows a significant positive relationship between soil erodibility index with silt content (O.96), Clay content (0.30) and Organic matter content (0.20) but significant negative relationship with sand content pH and permeability (table 2). Poesen*etal.*2003 had reported that increasing rock content consistently correlated with decreasing erosion rates, at all slopes because presence of rocks affects surface processes, protecting the soil from raindrop impact and overland flow energy. It is also, important to note that as proportion of silt and very fine sand in the soil increases the erodibility( Baver, 2006).This could be associated with the clay/ silty soil formed in between sandy walls was found seriously washing down the gully wall leaving the sandy walls hanging as shown in fihure 3.

**Table 2 Soil Erodibility Index (K) Correlation with Soil Properties**



|  |  |
| --- | --- |
| C:\Users\USER\Desktop\GULLY Erosion thesis\Rafin gora maps\IMG_20200123_122548_6.jpg | C:\Users\USER\AppData\Local\Microsoft\Windows\Temporary Internet Files\Content.Word\IMG_20200123_130153_1.jpg |

Figure 3: Washing of clay and silt rich soil (Long10° 16 ʹ 33 ʺ; Lat5° 25ʹ 54ʺ)

**Conclusion**

The study area is underlain by reddish, poorly sorted sandstone with geological structures like joint, cross bedding, herringbones structures, clay clast, lamina and biuturbation that displayed various implications on the structurally control (joint) of the active gullies with tendency of upstream expansion and greater impact on roads and houses. The acidic soil with low in organic matter content and high permeability in the study area classified into Sand (S), Loamy Sand (LM),Sandy Clay (SC) and Sandy Loamy and concluded that soil around location 4 and 13 were highly erodible with Erodibility index (EI) while the least erodible soil were located in L14 and L15

This EI show a significant positive relationship with silt content, Clay content and Organic matter content but significant negative relationship with sand content, pH and permeability.

**Recommendations**

1. Effective drainage system should be constructed within the community to reduce the impact of runoff in expansion of gullies.
2. The immediate stabilization of moderate sheet and rill erosion, and incipient gullies in the area by the community through vegetation or other mechanical means should be encouraged
3. Excavation of vulnerable claystone by the natives for building construction should be totally discouraged as more erosional problem is been created in an area where they are been excavated.

**References**

Adornado, H. A., Yoshida, M., &Apolinares, H. A. (2009). Erosion vulnerability assessment in REINA, Quezon Province, Philippines with raster-based tool built within GIS environment. *Agricultural Information Research*, *18*(1), 24-31.

ASTM 1979. "A procedure for the determination of ductile fracture toughness values using J integral techniques." *Journal of Testing and Evaluation* 7, no. 1 (1979): 49-56.

Baver, L. D. (1933). Soil porosity as an index of structure. *Soil Science Society of America Journal*, *14*(2001), 83-85.

Bennett, H. H. (1926). Some comparisons of the properties of humid-tropical and humid temperate American soils; with special reference to indicated relations between chemical composition and physical properties. *Soil Science*, *21*(5), 349-376.

Bobe, B. W. (2004). *Evaluation of soil erosion in the Harerge region of Ethiopia using soil loss models, rainfall simulation and field trials* (Doctoral dissertation, University of Pretoria).

British Standard (B.S. 1981) A procedure for the determination of ductile fracture toughness values using integral techniques.

Ezechi, J. I., &Okagbue, C. O. (1989). A genetic classification of gullies in Eastern Nigeria and its implications on control measures. *Journal of African Earth Sciences (and the Middle East)*, *9*(3-4), 711-718.

Gabriel, H. &Jibril, S. (2011) Geotechnical evaluation of soils in Kafari and its environs, North East Nigeria. *Continental Journal of Earth Sciences*, *5*(1), 20-31.

Igwe, C. A. (2003). Erodibility of soils of the upper rainforest zone, southeastern Nigeria. *Land Degradation & Development*, *14*(3), 323-334.

Igwe, C. A., &Ejiofor, N. (2005). Structural stability of exposed gully wall in Central Eastern Nigeria as affected by soil properties. *International agrophysics*, *19*(3), 215-222.

Mahmud, H. L., &Umaru, E. T. (2018). Impact of Gully Erosion on Landuse/Land Cover in Bida Town Niger State, Nigeria. *Intl. J. of Geography and Environmental Management*, *4*(2), 7-15.

Mbaya, L. A., Ayuba, H. K., &Abdullahi, J. (2012). An assessment of gully erosion in Gombe town, Gombe state, Nigeria. *Journal of Geography and Geology*, *4*(3), 110

Middleton, H. E. (1930). *Properties of soils which influence soil erosion* (No. 178). US Department of Agriculture.

Nigerian Meteorological Agency (NIMET, 2012). Agro-meteorological Bulletin, Quarterly Compilation Decadal, April-June, 2012. Pp: 1-27

Ofomata, G. E. K. (1981). Impact of road building, urbanisation and general infrastructural development on the Nigerian rainforest ecosystem. *Landscape Planning*, *8*(1), 21-29.

Ojo, O. J. &Akande, S. O. (2012). Hydrocarbon potential of Cretaceous sediments in the Lower and Middle Benue Trough, Nigeria: Insights from new source rock facies evaluation. *Journal of African Earth Sciences*, 64, 34-47.

Poesen, J., Nachtergaele, J., Verstraeten, G. &. Valentin, C., (2003) Gully erosion and environmental change: importance and research needs,Catena, 50 (2-4), pp. 91-133,

Rahaman, M. A. O., Fadiya, S. L., Adekola, S. A., Coker, S. J., Bale, R. B., Olawoki, O. A., ... & Akande, W. G. (2019). A revised stratigraphy of the Bida Basin, Nigeria. *Journal of African Earth Sciences*, *151*, 67-81.

Renard, P., & De Marsily, G. (1997). Calculating equivalent permeability: a review. *Advances in water resources*, *20*(5-6), 253-278.

Wall,W., Bergonse, R. V., & Reis, E. J. (1987). Theoretical constraints to gully erosion research:time for a re‐evaluation of concepts and assumptions?. *Earth Surface Processes and Landforms*, *36*(11), 1554-1557.

Wischmeier, W. H., & Smith, D. D. (1978). *Predicting rainfall erosion losses: a guide to conservation planning* (No. 537). Department of Agriculture, Science and Education Administration.