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Original Article

Classification of Soil Erodibility of Gully Sub-systems in Yola South, Adamawa State, Nigeria

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Abstract

This research work aimed to classify soil erodibility status of the gully sub-systems in Yola South Local Government Area, Adamawa State. Three (3) arable lands were selected based on their high severity of gully development namely Mbamba, Bole and Yolde Pate defined as sub-systems. The number of gully units was counted at each sub-system where soil samples were collected at the top, middle and bottom layers from each of the gully unit and analyzed based on the selected properties. Soil erodibility classification was estimated using Nomographic method. The result revealed that at Mbamba subsystem three (3) gullies were found, five (5) at Bole and four (4) were identified at Yolde pate In addition, soil erodibility class was found to be very high at Mbamba and Bole in all the gully units with K values ranged from 0.53-0.54 and 0.50-0.53, accordingly. Meanwhile, at Yolde pate sub-system unit 1 and 3 were classified with high erodibility status (0.40-0.42) while gully unit 2 and 4 classified as very high (0.46-0.47) respectively. These arable lands are seriously under devastating effects of gully destruction resulting in the loss of farmlands, nutrients and yield reduction. It is recommended therefore farmers in the area should adopt the use effective soil and conservation techniques and to ensure embracing proper land use management to avoid gully initiation and development.

Keywords*: Gully, Erosion, Erodibility, Soil, Yola*

INTRODUCTION

Soil erosion is a result of many factors, such as rainfall intensity, steepness of slope, length of slope, vegetation cover, and management practices. Besides all this, the inherent properties of a soil influence the ability of water to detach and transport soil particles. This intrinsic property is classified as soil erodibility (Belasri *et al.,* 2017). Agostina *et al.,* (2021) stated that gully erosion is a geo-hydrological phenomenon contributing significantly to land degradation. Gully erosion results in a large amount of soil loss and infrastructure destruction and has negative hydrological impacts on watershed functions, leading to increased runoff and sediment connectivity in the landscape (Wang *et al.,* 2022). Yet, its extent and spatio-temporal distributions are affected by the dynamic interaction of several environmental factors (Setargie *et al.,* 2023).An estimation at global level showed that arable land loses more than 10 million hectares of soil per year (Bagarello *et al.,* 2012) and this is severe threat especially in countries depending on agricultural activities like Nigeria. Soil erodibility is different from soil erosion in a sense that the total erosion may be influenced by other factors like rainfall-climate, crops, management of the land etc. Some soils erode more readily than others even when all other factors are same. Soil texture (sand, slit, and clay composition), organic matter content, structure and permeability in addition to iron, aluminum and sodium contents are a few of the major factors that affect soil erodibility. Soil erosion depends not only on rainfall erosivity but also on the soil's resistance to erosion, which is usually measured as the soil erodibility factor K (Singh and Khera, 2010).

Many different methods are used to measure K values of soils which includes Universal Soil Loss Equation (USLE) given by Wischmeier and Smith (1978), Fuzzy logic based program FUZKBAS given by Torri *et al*. (1997), Water Erosion Prediction Project (WEPP), GIS-based techniques (Ogbonna, 2012), machine learning techniques (Abraham *et al.,* 2020), Nomographic method by Wischmeier *et al*. (1971) among others. But these methods and their process are costly and time consuming. In this study, the Nomographic method of Wischmeier *et al*. (1971) was used for estimating erodibility from basic soil properties in the area. In Yola South Local Government Area, Adamawa State most of the arable lands are seriously affected by gully erosion leading to damaging of limited available farmlands. No adequate information on the status of soil erodibility classification of these areas which may use in planning adopting preventive and effective control measures. Therefore, it is highly imperative to empirically classify erodibility class of the soils in the area. Thus, this research work aimed to classify soil erodibility status of gully sub-systems in Yola South Local Government Area, Adamawa State.

a. Gully Unit 1 at Yole pate area

b. Gully Unit 1 at Mbamba area

c. Gully Unit 3 at Bole pate

d. Gully Unit 2 Profile at Mbamba area

Plate 1 a-d. Shows pictures of some gully erosions in the study areas.

MATERIALS AND METHOD

The Study Area

The study area is located in Yola-South Local Government Area of Adamawa State, Nigeria. The study area lies between Latitude 9˚ 14' North of the Equator and Longitude 12˚ 28' East of the Greenwich- Meridian (Fig. 1) having an average elevation of about 192 m (Adebayo, 2020). The area has a land mass of 2,310.05 km^2. In addition, three arable lands were selected in the area namely Yolde Pate (9^o 11' - 9^o 13' North of the Equator and Longitude 12^o 26' -12^o 28' East of the Greenwich Meridian with elevation of 157-162 m) while Mbamba (9^o 10' - 9^o 11' North of the Equator and Longitude 12^o 31' -12^o 33' East of the Greenwich Meridian having an elevation ranges from 166-196 m) and Bole (9^o 8' - 9^o 10' North of the Equator and Longitude 12^o 28' -12^o 31' East of the Greenwich Meridian with an elevation ranges from 175-219 m).

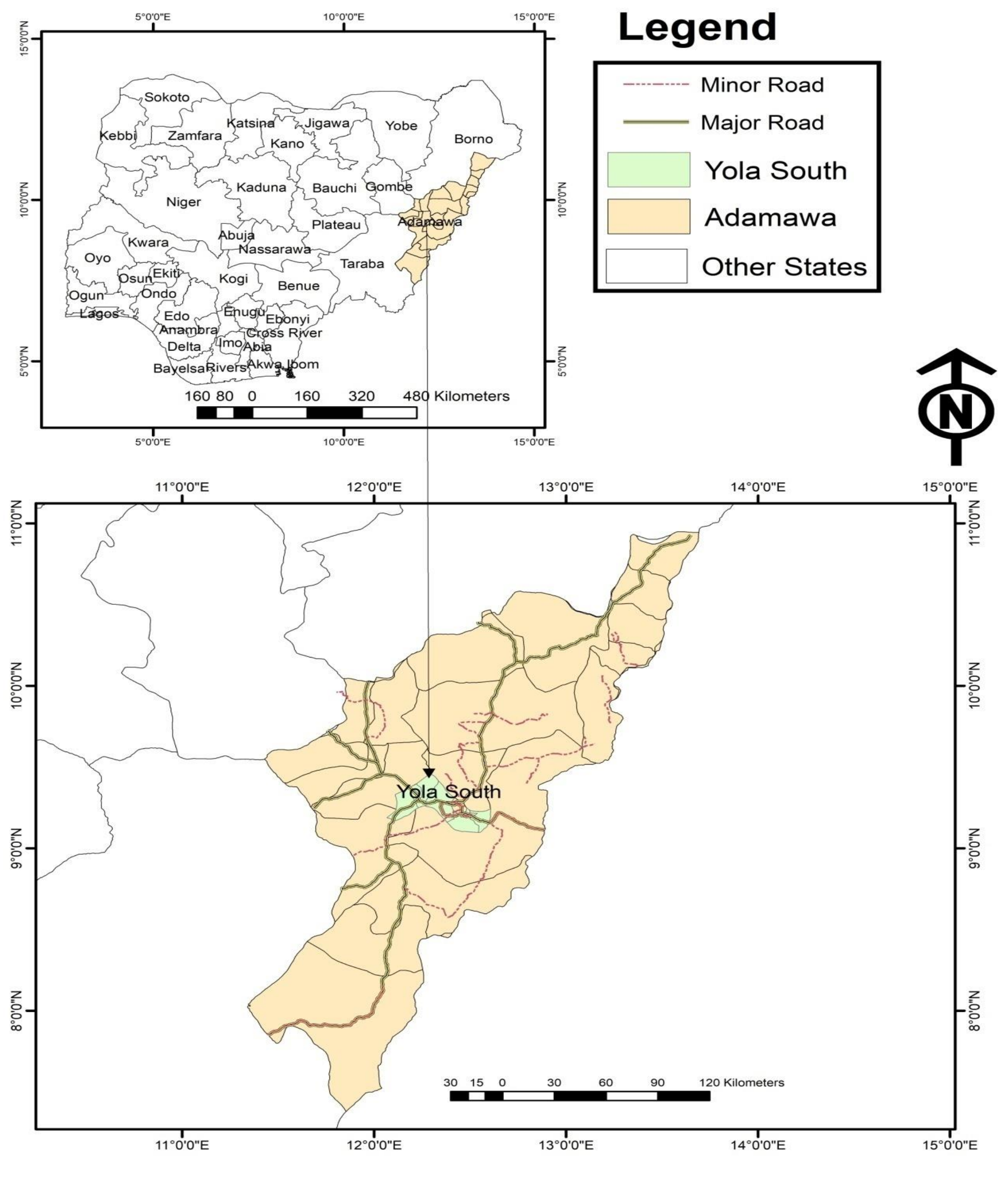

Figure 1. Map showing the study area

Gully sites selection

Three (3) arable lands were selected in the study area namely Mbamba, Bole and Yolde Pate based on the devastating effects of gullies in these areas. At each of the arable land, gully affected area was delineated and defined as gully subsystem. At the subsystems each gully unit (single outlet connected to more than one gully) was identified accordingly.

Identification of gully units from satellite images in the area

This involved the combination of GIS and remote sensing through the use of the satellite imagery techniques. The size of each gully sub-system in the study area were determined by importing the imagery for the year 2024 into ArcGIS 13.1 software environment and identified the existing number of gully units in the area.

Soil sample collection

Soil samples were taken along the gully wall layers (top, middle and bottom) sampling points per gully profile (gully unit) in order to analyze the soil properties, the technique employed is in accordance with (Mallam, *et al.*, 2016). The collected soil samples from the top middle and bottom of the gully walls were air-dried, crushed using a wooden mortar and pestle, and then sieved through a 2 mm mesh. The sieved samples were stored in polythene bags for laboratory analysis of the soil properties.

Laboratory Analysis

Four (4) physicochemical properties (soil texture, soil structure, organic matter and permeability) of soil erodibility functions that are used in Nomograhic charts analyses were determined using standard laboratory procedures. Soil particle size as described by Trout, *et al.*, (1987) Organic carbon was quantified by the Walkley and Black (1934) wet dichromate oxidation and converted to organic matter by multiplying it by 1.724, soil permeability code was determined from the National Soils Handbook and soil structure code was obtained using soil textural Pyramid (USDA, 1983). The soil texture class has been used to determine the permeability code of the soil and structure code described by Wischmeier and Smith (1978) as presented below on Table 1 and 2 and Nomographic chart used in estimating the soil erodibility factor was also depicted on Fig. 2. Soil erodibility factor equation based on five soil parameters is given as;

$$K = 2.1\, M^{1.14}\, (10^{-4})\, (12 - a) + 3.25\, (b-2) + 2.5\, (c-3).$$

K = soil erodibility factor
M = percentage silt, very fine sand and sand > 0.10 mm
a = organic matter content
b = structure of the soil
c - permeability of the soil

Classification of soil erodibility

The **soil** erodibility was classified using soil erodibility nomograph chart curve method by United States Department of Agriculture (USDA, 1987). It broadly applies to cropped surface soils; it should not be extrapolated beyond the curves shown on the nomograph. For example, a value for organic matter greater than four percent (> 4%) is not recommended or allowed (USDA, 1987). The definitions and variable descriptions (Table 1 and 2) used in the nomograph must be carefully followed. With the results, K value may be derived from the nomograph chart curve described on Fig. 2. The soil erodibility classifications are depicted on Table 3 below.

Table 1. Soil permeability code based on soil texture class National Soil Handbook

Soil texture	Permeability code
Heavy clay, Clay	6
Silty clay loam, Sandy clay	5
Sandy clay loam, Clay loam	4
Loam, Silt loam	3
Loamy sand, Sandy loam	2
Sand	1

(USDA, 1987).

Table 2. Permeability and soil structural codes

Permeability class	Permeability code	Structural category	Code
Rapid	1	Very fine granular	1
Moderate to rapid	2	Fine granular	2
Moderate	3	Medium or coarse granular	3
Slow to moderate	4	massive or platy	4
Blocky,			
Slow	5		
Very slow	6		

Wischmeier (1978)

Table 3. Soil Erodibility Classification System

Soil Erodibility Classification	K estimated Values
Very high	> 0.45,
High	0.35-0.45
Moderate	0.25-0.35
Low	0.2-0.25
Very low	< 0.2

(Wischmeier, 1978:USDA, 1987).

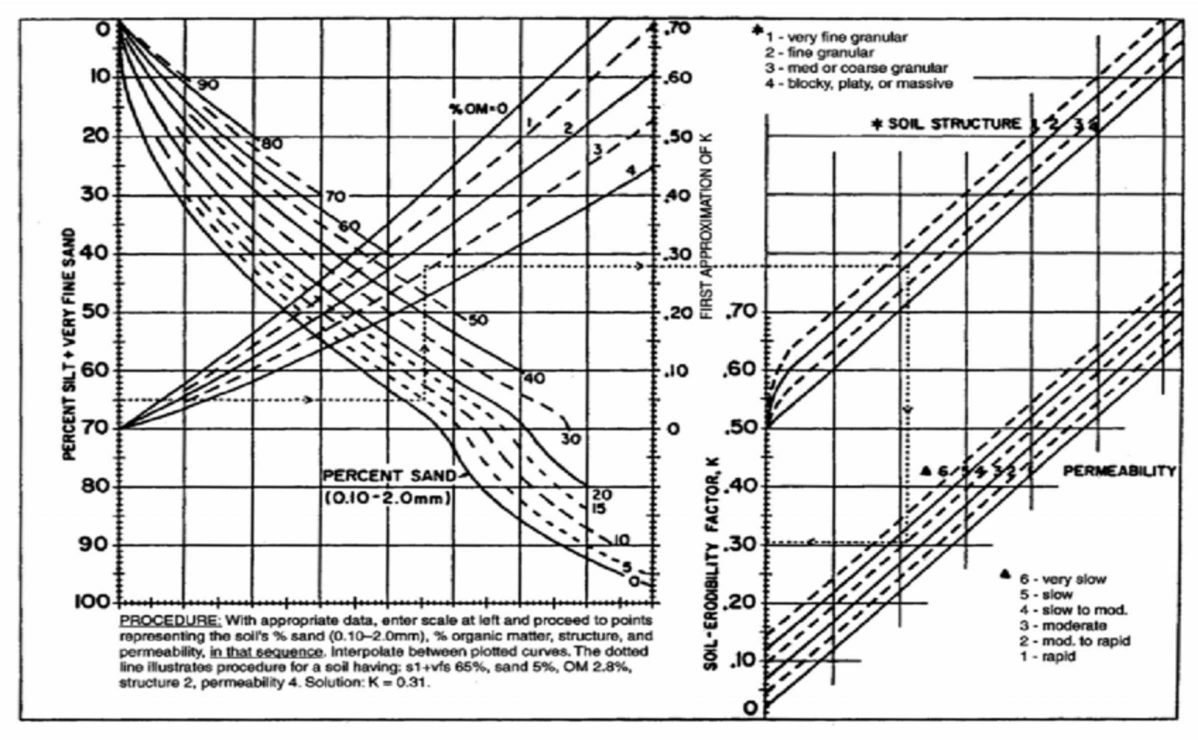

Fig. 2. Nomographic chart curve used in estimating the soil erodibility factor (USDA, 1987).

Statistical Analysis

The obtained data were subjected to descriptive and inferential statistical analysis using SPSS version 23 while nomographic chart was used to classified erodibility status of the soil.

RESULTS AND DISCUSSIONS

Classification of soil erodibility status of the identified gully units at Mbamba study area

Results on the identified gullies at Mbamba area are depicted on figure 3. Three (3) gullies were identified while selected soil properties affecting erodibilty and the soil erodibility classification of each gully unit are presented in Table 4 and 5 respectively. The results revealed that at unit 1 gully loamy sand soil dominated the top and middle layers with the corresponding values of 79.39-83.74 % of sand content while, at the bottom was described as sandy loam (77.36 %). Low OM (1.36 %-1.25 %) decreases with depth, having code 2 of both texture and permeability class characterized as moderate to rapid permeability and moderate to coarse granular structure. The erodibility status of the soil was rated as very high with the observed mean K value of 0.53. This could be connected to aggregate stability variations of the soil with high sand content which are more and easily detachable. Similar result was reported by Abdulqadir *et al.,* (2025) in the area and Osujieke *et al.,* (2020) in Mbano, South-east Nigeria that the soils are susceptible to erosion. Sadiq (2020) reported a similar result of K value (0.53-0.62) in the area due to the high content of sandy particles coupled with low OM. The soil may have no strong binding potentials within the aggregates that will aid the resistance of the soil. Thus, organic matter increases aggregation in the soil which tends to reduce soil erosion (USDA, 1987).

For gully unit 2 in the sub-system of Mbamba area, it was observed that high percent of sand particles predominated in all the identified layers (78.86-85.68 %) which decreases with depth. Loamy sand was found at top and bottom layers and sandy loam was found at the middle layer with low OM content (1.18-1.58 %) having similar textural and permeability code of rated moderate to rapid permeability and moderate to coarse granular structure as described in Table 1. An estimated mean K value of 0.54 rated as very high susceptibility to erosional processes. One could observed that sand particles dominated the identified horizons which is easily detachable and erodible by rainstorm, intensity and run-off. Ibeje, (2016) have evaluated erodibility status of soils in some areas of Imo and Abia states of Nigeria and concluded that there was, respectively, a strong inverse relationship between clay and silt contents and erodibility index. This suggests that increases in clay and silt lead to a decrease in soil erodibility and this is not in harmony with sustainable crop production since clay minerals play important role in soil fertility status of a given location.

Furthermore, at unit 3 gully of Mbamba area loamy sand soil was found to have dominated the top and middle layers while sandy loam was observed at the bottom layer. Similarly, the OM content was low (1.20-1.38 %) with moderate to rapid permeability having structural code of 3 described as moderate to coarse granular structure. The mean K value of 0.53 was recorded classified as very high erodible soil. Largely, it could be noted that K values were high in all the gully units which signifies high and effective estimation of K using nomographic method. In contrast, the findings of Singh and Khera, 2010) reported that soil erodibility factor (K) estimated of Himalayas region in North-west India using nomograph varied from 0.14 to 0.46 which are considered low compared to fuzzy logic method (Torri *et a.l* 1997) observed values, thus rated as erodible.

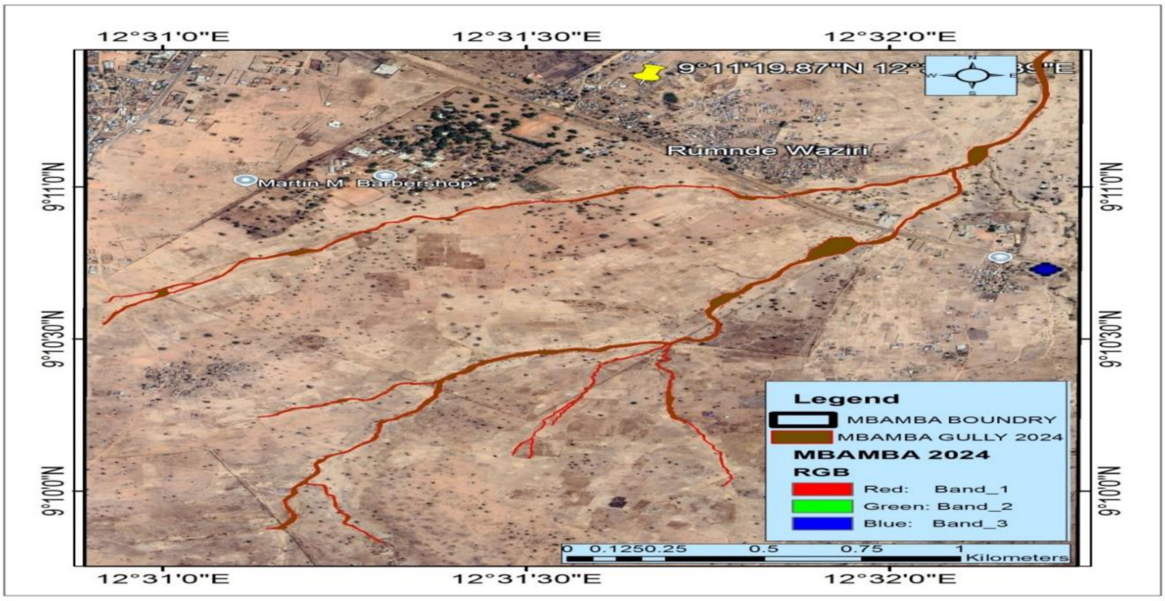

Figure 3: Satellite Imagery Map of the studied gullies at Mbamba area **Source**: (Author's Analysis, 2025).

Classification of soil erodibility status of the identified gully units at Bole study area

Results on the identified studied gullies at Bole area are portrayed on figure 4. The results revealed that five (5) gullies were observed in the area where selected soil parameters affecting erodibility and the soil erodibility classification of Bole area are presented in Table 4 and 5. Gully unit 1 layers were dominated with high percent of sand content ranging from 76.99-86.10 % followed by silt (7.50 %-12.73 %) and then clay (6.38 %-11.52 %) classified as loamy sand at top layer and sandy loam at the middle and bottom layers respectively. It has moderate to rapid permeability at all the layers having permeability and textural codes of 2 each with low OM content ranging from 1.25-1.59 % which gradually reduces with depth. Soils with less than 2% organic matter can be considered erodible (Ekwue, 1990). In addition, moderate to coarse granular was described in all the layers with similar code 3. The soil erodibility classification of the gully site was very high with an average K value of 0.50. However, due to high sand content of soils infiltration rates will be high thereby reducing the runoff amount and inconsequence decreasing the erodibility of the soil. This assertion is in conformity with the report of Bamanga *et al.,* (2024b) of some Wukari soils in Taraba state

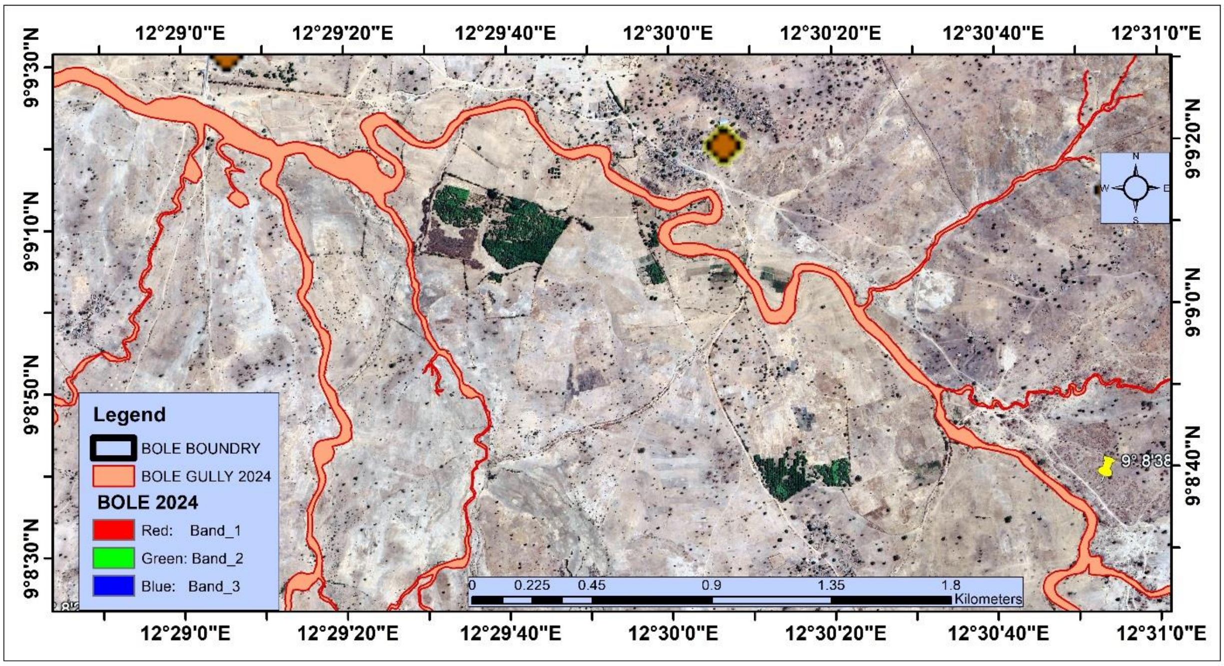

Figure 4: Satellite Imagery Map of the studied gullies at Bole area **Source**: (Author Analysis, 2025).

Furthermore, similar trends of high sand % (78.15 %-84.47 %) classified with loamy sand to sandy loam, low OM content (1.10-1.52 %) having textural and permeability of 2 at all the layers classified as moderate to rapid permeability and moderate to coarse granular structure (3) were identified at gully unit 2 in sub-system of Bole study area as presented on Table 5. The mean K value of 0.51 was recorded and classified as very high erodible soils. Soils with larger sand and silt proportions are more vulnerable to water erosion due to lack of stability of soil particles (Abdulqadir *et al.,* 2025).

Moreover, at unit 3 gully erosion in the sub-system, it was observed loamy sand textural class dominated the all layers of the gully with the corresponding values of sand ranging from 79.17-84.46 % with code 2 of both texture and permeability rated as moderate to rapid. Otuaro *et al.,* (2024) revealed that high infiltration rate was found at low silt and clay percentage in some areas in Minna. Thus, these soils may be less prone to water erosion. The OM content decreases with depth (1.78 %-1.18 %) described as low to very low, with a code of 3 of moderate to coarse granular structure as portrayed in Table 1. The soils has very high susceptibility to erosion having recorded mean K value of 0.50 rated as very high as described in Table 2 accordingly.

Table 4. Soil properties of the selected farm location related to soil erodibility

Location	Depth	Layers	Soil textural Proportions			Soil textural class	Soil textural class code	OM %	Permeability code	Permeability code description	Structural code	Structural code Description
			SAND %	CLAY %	SILT %							
	0-34	TOP	60.93	15.46	23.60	Loam	3	1.73	3	Moderate	4	Massive or platy
YP 001	34-82	MIDDLE	74.61	11.24	14.14	Sandy Loam	2	1.31	2	Moderate to Rapid	3	Moderate to Coarse Granular
	82-123	BOTTOM	79.63	10.14	10.22	Sandy Loam	2	1.19	2	Moderate to Rapid	3	Moderate to Coarse Granular
	0-28	TOP	64.97	17.84	17.18	Loam	3	1.47	3	Moderate	4	Massive or platy
YP 002	28-78	MIDDLE	73.96	12.99	13.03	Sandy Loam	2	1.35	2	Moderate to Rapid	3	Moderate to Coarse Granular
	78-111	BOTTOM	80.23	10.17	9.58	Loamy Sand	2	1.25	2	Moderate to Rapid	3	Moderate to Coarse Granular
	0-37	TOP	62.93	18.06	19.00	Loam	3	1.68	3	Moderate	4	Massive or platy
YP 003	37-67	MIDDLE	71.65	14.65	13.68	Sandy Loam	2	1.28	2	Moderate to Rapid	3	Moderate to Coarse Granular
	67-90	BOTTOM	78.60	10.13	11.25	Sandy Loam	2	1.16	2	Moderate to Rapid	3	Moderate to Coarse Granular
	0-18	TOP	64.82	18.73	16.44	Loam	3	1.66	3	Moderate	4	Massive or platy
YP 004	18-35	MIDDLE	82.88	13.83	3.27	Loamy Sand	2	0.87	2	Moderate to Rapid	3	Moderate to Coarse Granular
	35-78	BOTTOM	80.70	13.45	5.84	Loamy Sand	2	1.25	2	Moderate to Rapid	3	Moderate to Coarse Granular
	0-33	TOP	86.10	6.38	7.50	Loamy Sand	2	1.59	2	Moderate to Rapid	3	Moderate to Coarse Granular
BL 001	33-67	MIDDLE	78.36	11.52	10.10	Sandy Loam	2	1.27	2	Moderate to Rapid	3	Moderate to Coarse Granular
	67-122	BOTTOM	76.99	10.26	12.73	Sandy Loam	2	1.25	2	Moderate to Rapid	3	Moderate to Coarse Granular
	0-56	TOP	84.47	9.47	6.05	Loamy Sand	2	1.52	2	Moderate to Rapid	3	Moderate to Coarse Granular
BL 002	56-89	MIDDLE	78.15	12.01	9.83	Sandy Loam	2	1.36	2	Moderate to Rapid	3	Moderate to Coarse Granular
	89-133	BOTTOM	80.45	10.33	9.20	Loamy Sand	2	1.10	2	Moderate to Rapid	3	Moderate to Coarse Granular
	0-34	TOP	84.46	9.60	5.93	Loamy Sand	2	1.78	2	Moderate to Rapid	3	Moderate to Coarse Granular

Table 4. Soil parameters of the selected farm location related to soil erodibility continuation

Location	Depth	Layers	Soil textural Proportions SAND %	CLAY %	SILT %	Soil textural class	Soil textural class code	OM %	Permeability code	Permeability code description	Structural code	Structural code Description
BL 003	34-67	MIDDLE	79.77	10.32	9.90	Loamy Sand	2	1.42	2	Moderate to Rapid	3	Moderate to Coarse Granular
	67-107	BOTTOM	79.17	10.05	10.77	Loamy Sand	2	1.18	2	Moderate to Rapid	3	Moderate to Coarse Granular
	0-22	TOP	87.95	6.56	5.48	Loamy Sand	2	1.72	2	Moderate to Rapid	3	Moderate to Coarse Granular
BL 004	22-34	MIDDLE	80.46	10.61	8.91	Loamy Sand	2	1.41	2	Moderate to Rapid	3	Moderate to Coarse Granular
	34-89	BOTTOM	77.55	11.12	11.32	Sandy Loam	2	1.14	2	Moderate to Rapid	3	Moderate to Coarse Granular
	0-36	TOP	86.00	8.80	5.19	Loamy Sand	2	1.76	2	Moderate to Rapid	3	Moderate to Coarse Granular
BL 005	36-89	MIDDLE	82.52	10.30	7.17	Loamy Sand	2	1.38	2	Moderate to Rapid	3	Moderate to Coarse Granular
	89-133	BOTTOM	81.09	9.48	9.42	Loamy Sand	2	1.25	2	Moderate to Rapid	3	Moderate to Coarse Granular
	0-26	TOP	83.74	8.11	8.14	Loamy Sand	2	1.36	2	Moderate to Rapid	3	Moderate to Coarse Granular
MB 001	26-56	MIDDLE	79.39	11.17	9.42	Loamy Sand	2	1.34	2	Moderate to Rapid	3	Moderate to Coarse Granular
	56-89	BOTTOM	77.36	12.56	10.06	Sandy Loam	2	1.25	2	Moderate to Rapid	3	Moderate to Coarse Granular
	0-36	TOP	85.68	6.59	7.71	Loamy Sand	2	1.58	2	Moderate to Rapid	3	Moderate to Coarse Granular
MB 002	36-78	MIDDLE	78.86	9.66	11.46	Sandy Loam	2	1.48	2	Moderate to Rapid	3	Moderate to Coarse Granular
	78-123	BOTTOM	77.79	12.76	9.43	Sandy Loam	2	1.18	2	Moderate to Rapid	3	Moderate to Coarse Granular
	0-40	TOP	83.38	8.45	8.15	Loamy Sand	2	1.35	2	Moderate to Rapid	3	Moderate to Coarse Granular
MB 003	40-78	MIDDLE	81.92	10.07	8.00	Loamy Sand	2	1.38	2	Moderate to Rapid	3	Moderate to Coarse Granular
	78-112	BOTTOM	78.65	14.35	6.99	Sandy Loam	2	1.20	2	Moderate to Rapid	3	Moderate to Coarse Granular

Keys: YP: Yolde Pate, BL:Bole MB: Mbamba

Table 5. Estimated soil erodibility factor (K) using USDA Nomorgraphic chart method

Location	Depth	Layers	First approximation of K’	Final approximation of K	Erodibility classification
YP 001	0-34	Top	0.25	0.32	Moderate
	34-82	Middle	0.45	0.43	High
	82-123	Bottom	0.53	0.52	Very High
		Average	**0.41**	**0.42**	**High**
YP 002	0-28	Top	0.44	0.47	Very High
	28-78	Middle	0.47	0.45	Very High
	78-111	Bottom	0.50	0.48	Very High
		Average	**0.47**	**0.46**	**Very High**
YP 003	0-37	Top	0.25	0.32	Moderate
	37-67	Middle	0.44	0.40	High
	67-90	Bottom	0.49	0.48	Very High
		Average	**0.39**	**0.40**	**High**
YP 004	0-18	Top	0.36	0.42	High
	18-35	Middle	0.53	0.51	Very High
	35-78	Bottom	0.50	0.48	Very High
		Average	**0.46**	**0.47**	**Very High**
BL 001	0-33	Top	0.50	0.48	Very High
	33-67	Middle	0.51	0.48	Very High
	67-122	Bottom	0.53	0.54	Very High
		Average	**0.51**	**0.50**	**Very High**
BL 002	0-56	Top	0.56	0.54	Very High
	56-89	Middle	0.50	0.49	Very High
	89-133	Bottom	0.52	0.50	Very High
		Average	**0.52**	**0.51**	**Very High**
BL 003	0-34	Top	0.53	0.51	Very High
	34-67	Middle	0.52	0.51	Very High
	67-107	Bottom	0.49	0.48	Very High
		Average	**0.51**	**0.50**	**Very High**
BL 004	0-22	Top	0.58	0.59	Very High
	22-34	Middle	0.51	0.49	Very High
	34-89	Bottom	0.52	0.51	Very High
		Average	**0.53**	**0.53**	**Very High**
BL 005	0-36	Top	0.54	0.53	Very High
	36-89	Middle	0.51	0.50	Very High
	89-133	Bottom	0.53	0.51	Very High
		Average	**0.52**	**0.51**	**Very High**
MB 001	0-26	Top	0.55	0.53	Very High
	26-56	Middle	0.53	0.52	Very High
	56-89	Bottom	0.53	0.54	Very High
		Average	**0.53**	**0.53**	**Very High**
MB 002	0-36	Top	0.59	0.60	Very High
	36-78	Middle	0.54	0.53	Very High
	78-123	Bottom	0.53	0.51	Very High
		Average	**0.55**	**0.54**	**Very High**
MB 003	0-40	Top	0.59	0.58	Very High
	40-78	Middle	0.53	0.51	Very High
	78-112	Bottom	0.52	0.51	Very High
		Average	**0.54**	**0.53**	**Very High**

Keys: YP: Yolde pate, **BL**:Bole **MB**: Mbamba

Similarly, high content of sand (77.55-87.95 %) was observed to have dominated the layers of gully unit 4 classified as loamy sand and sandy loam characterized with moderate to rapid permeability, low OM content ranging from 1.14-1.72 % and moderate to coarse granular structure with code 3 as depicted on Table 1 respectively. The final estimated mean K value of the unit 4 is 0.53 classified as very high erodible soil. Textural variability of the soil might be attributed to high value of K estimated in the area. Hence, Belasri *et al.,* (2017) have explained that erodibility is controlled by four major soil properties: soil texture (particle size distribution), soil structure, organic matter content, and permeability.

Similar trend of loamy sand soil at all the layers, with low OM (1.25-1.76 %), moderate to rapid permeability with code 2 and moderate to coarse granular structure with code 3 were found at gully unit 5 as were described in Table 1. The K estimation revealed that the soil has very high susceptible to erosion considering the observed mean value 0.51.The soils are considered highly erodible which might be connected to low OM as was also reported by (Ekwue, 1990). Morgan (2001) suggested that soil Erodibility decreases linearly with increasing organic content over the range of 0 to 10%. This is because organic matter and chemical constituents of the soil are important because of their influence on the stability of aggregates which reduces erodibility.

Classification of soil erodibility status of the identified gully units at Yolde pate study area.

At Yolde pate area four (4) gully units were identified as shown in figure 5. Results on the selected soil parameters affecting erodibility and the soil erodibility classification of Yolde pate are presented in Table 4 and 5. At gully unit 1 of Yolde pate sub-system area loamy soil (60.93 % sand, 15.46% clay and 23.60 % silt) dominated the top layer of the gully while sandy loam was observed at middle and bottom layers accordingly. The soil textural class and permeability codes for the three layers are 3, 2 and 2 with moderate to rapid permeability. The organic matter (OM) content of the soil is was low (1.19- 1.73 %). In addition, the structural codes are 4, 3 and 3 described as massive or platy and moderate to coarse granular as described in Table 1. The estimated mean K value for the unit 1 gully of Yolde pate is 0.42 generally classified as high erodibility. This finding is in conformity with the result of Sadiq (2020) who reported that soil erodibility status of Yolde pate was high to very high (0.53).

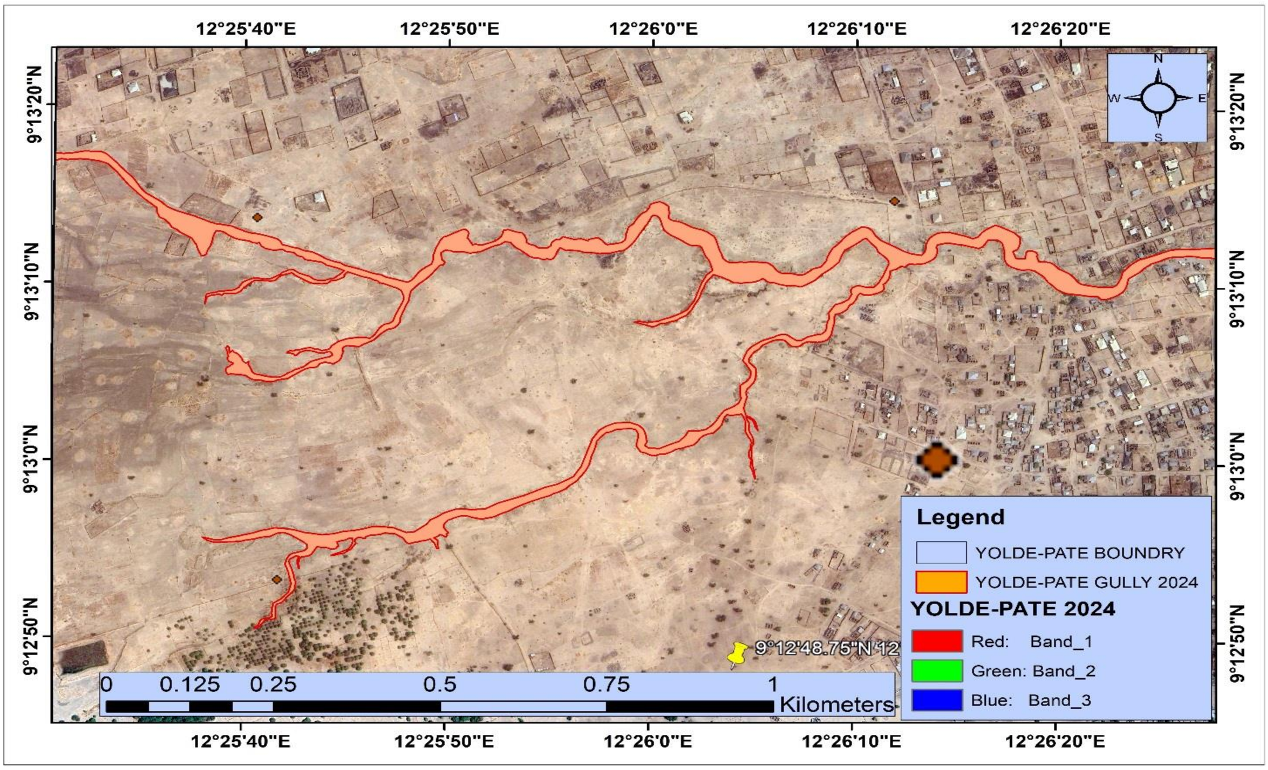

Figure 5: Satellite Imagery Map of the studied gullies at Yolde pate area **Source**: (Author Analysis, 2025).

Similarly, gully unit 2 of Yolde pate area is described with loamy, sandy loam and loamy sand soil textures at top, middle and bottom layers having structural and permeability codes of 3, 2 and 2 classified as moderate to rapid permeability with low OM content. The structural codes are 4, 3 and 3, defined as massive or platy and moderate to coarse granular as described in Table 4 accordingly. Furthermore, the final estimated mean K value of 0.46 is classified as very high erodibility status as depicted in Table 5. This might be linked to the high content of sandy particles which increases down the layers (Table 4). In a similar finding, Ibeje (2016) found that sand as well as soil permeability of some soils of Imo and Abia states have a significantly high positive correlation with soil erodibility. Some soils erode more readily than others even when all other factors are same.

Furthermore, loamy textured soil (62.93 % sand, 18.06 % clay and 19.00 % silt) is found at top layer of unit 3 gully of Yolde pate while middle and bottom layers of the gully were dominated by sandy loam soil with more sand particles, greater than 70 % as presented in Table 4. Textural class and permeability codes were revealed to have similar values of 3, 2 and 2 characterized with moderate to rapid permeability. The OM content of the soil was low ranged from 1.16-1.68 % which decreases down the layers. In addition, 4, 3 and 3 are the structural codes described with massive and moderate to coarse granular. The mean K value of 0.40 (Table 4) classified with high erodibility. Despite the fact the area is characterized with moderate to rapid permeability which may reduce high run-off that causes erosion formation and development, it is classified with high erodibility status this might be linked to presence of high percent of coarse textured soil (Table 4), which are easily detachable and transported than clayey soils.

In addition, at gully unit 4 of Yolde pate sub-system loamy and loamy sand soils dominated the layers having high percent of sand (64.82-82.88 %).The textural and permeability codes are 3, 2 and 2 classified with moderate to rapid permeability with very low to low (0.87 %-1.66 %) OM content. The structural code is generally 4, 3 and 3 at the top, middle and bottom layers of the gully described with massive or platy and moderate to coarse granular. The estimated mean K value of 0.47 classified as very high (Table 5.) Generally, it could be observed that in all three (3) study areas, the K values generated were rated as highly erodible based on the nomographic method. However, this method was largely considered effective in estimating erodibility level or susceptibility most especially in areas with low OM (< 2 %). Angima *et al.*, (2003) explained that soil erodibility (K) factor is applicable to most tropical soils and was found to strongly correlate with soil loss. It is also important to state that soil with relatively low erodibility factor may show signs of serious erosion, yet a soil could be highly erodible and suffer little erosion (Nyakatawa *et al.,* 2001). This is because soil erosion is a function of many factors as stated in the universal soil loss equation (USLE).

Regression results on the effect of erodibility factor (FK) on gully formation and development in the study areas.

Based on the regression results presented on Table 6 as soil erodibility factor (FK) is the primary focus, the inclusion of morphometric variables such as depth, width, length, and cross-sectional area (CSA) significantly enhanced the explanatory power of the model. All predictors were statistically significant ($p < 0.05$), with average width emerging as the strongest contributor, followed by length and FK. Importantly, the collinearity statistics confirm the robustness of the model: tolerance values were all above 0.5 and VIF values remained below 2, indicating no serious multicollinearity among the predictors. This strengthens confidence that the observed relationships are reliable, with the combined variables explaining approximately two-thirds of the variation in gully erosion. This findings further explained the role of soil erodibility as an intrinsic property influencing detachability and transportation of soil particles as also reported by (Belasri *et al.,* 2017).

Table 6. Regression Analysis on the effect of erodibility factor (FK) on gully formation and development in the study areas.

Coefficients [a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	.991	.440		2.251	.032		
	Depth	.475	.170	.219	2.793	.020	.706	1.416
	Average Width	.663	.108	.493	6.154	.000	.773	1.293
	Length	.457	.078	.361	5.884	.000	.715	1.398
	CSA	.232	.084	.172	2.772	.019	.523	1.911
	FK	.434	.129	.310	3.375	.014	.641	1.561

a. Dependent Variable: Gully

R= .841[a], $\mathbf{R^2}$=.708, **Adj** $\mathbf{R^2}$=.659, **F**=14.544, **P**-value =0.000

CONCLUSIONS

Soil erodibility of the gully sub-systems revealed high susceptibility of the arable lands to further devastation by gully expansion and development most especially at Mbamba and Bole farmlands which are classified as very high susceptible. Therefore, it is recommended that farmers in the study areas should employ effective and proper land use practices and management to avoid excessive formation of rills and gullies erosion in the area. Thus, the soils are classified with high to very high erodibility. In addition, further research should be conducted using different methods to compare and validate the results obtained in this research of Nomorgraphic method respectively.

AUTHOR'S CONTRIBUTIONS

The first author handled the data collection, literature review and analysis while results interpretation and discussions were managed by the second author.

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