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An Estimation of Erodibility Status of Some Selected Arable Lands Using Nomographic Chart Method in Yola South, Adamawa State Nigeria

A. A. Sadiq[1*]

[1]Department of Agricultural Technology, Adamawa State Polytechnic, P.M.B. 2146, Yola, Adamawa State, Nigeria.

Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

Aim: To estimate the soil erodibility status of some selected arable lands in Yola South using Nomograpic chart curve method.
Place and Duration of Study: Arable lands of Yola south LGA of Adamawa State, Nigeria during 2019-2020 seasons.
Methodology: Biophysical features of the selected farmlands were observed through on-farm survey where five representative soil samples were collected at the each selected farm locations in the study area to a depth of 15 cm using auger method, where soil properties that are related to erodibility indices (particle size distribution, porosity, Organic matter) were analyzed using standard laboratory procedures.
Results: The results shows that the soils at Yolde pate, Bole I, Modere and Anguwan Tabo farm locations were very highly erodible with an estimated corresponding values of K =0.53, 0.58, 0.62 and 0.58 respectively. Similarly, areas with highly erodible soils were found at Wuro-chekke with an estimated K value of 0.40, Bole II 0.40, Mbamba Mission 0.42 and Mbamab Kona 0.43 correspondingly. Generally, the soils of the area were classified as high-very highly susceptible to erosion with an estimated K values ranges from 0.40-0.62 which might be connected to low OM

**Corresponding author: Email: sadiqhsadiq6@gmail.com;*

content of soils (1.52-2.15 %), dominated with moderate to slow permeability status and platy structure.
Conclusion: It is therefore recommended the further research in order to validate this research work by the use empirical model methods and to make comparison and correlation with the soil properties for appropriate recommendation on conservation farming in the area.

Keywords: Arable land; chart; erodibility; estimation; nomograph; Yola South; Nigeria.

1. INTRODUCTION

Soil erosion has continuously depleted agricultural lands reducing soil quality and productivity; this has resulted in increase in the use of fertilizer and increase in energy requirement for crop production [1]. An estimation at global level showed that arable land present more than 10 million hectare of soil loss per year [2] and this is severe threat especially in countries depending on agricultural activities. Water erosion has been the most widely studied of the three types of erosion, and is arguably the one that affects the greatest land area [3]. In the north-eastern sub region of Nigeria soil erosion may account for as much as 21tons of top soil loss per hectare per year [4]. However, the potential for erosion is dependent on certain factors which include soil nature/characteristics, nature of slope/topography, presence of vegetation and climatic conditions, [5]. Soil erodibility is defined as the susceptibility of soil to erosional processes [2] Erodibility is controlled by four major soil properties: soil texture (particle size distribution), soil structure, organic matter content, and permeability [6]. Some soils erode more readily than others even when all other factors are same. To calculate soil erodibility, many strategies have been researched to understand soil erodibility, including measurements of physical and chemical soil properties, instrumental measurements, mathematical models, and graphical methods [7]. The direct measurement of soil erosion in large plots under natural rainfall over long periods is a time-consuming and costly method [8;9;10]. Each estimation method differs in terms of applicability, even within the same area, because the different estimation methods include different physical and chemical soil properties [11;12]. Consequently, the estimated results can significantly differ among methods because soil conditions vary by region [11;12]. The methods to estimate soil loss intensity are numerous the Universal Soil Loss Equation (USLE) [13], and the revised version (RUSLE) [14] is still frequently used to predict soil loss at the plot scale and this process is costly and time consuming. For those soils for which a K value is not available, a K value can be estimated using the soil erodibility nomograph chart curve method [15]. It seems to broadly apply to cropped surface soils, it should be 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 [15]. The definitions and variable descriptions used in the nomograph must be carefully followed [15]. With the results of these analyses, K value may be derived from the nomograph chart curve described on Fig. 1. The soil erodibility is classified into the following groups; very high > 0.45, high = 0.35-0.45, moderate = 0.25-0.35 0.2-0, 25 low and very low = < 0.2 respectively. Therefore, this study aim at estimating erodibility status of some selected arable lands in Yola South using USDA Nomographic chart method.

2. MATERIALS AND METHODS

2.1 Study Area

The study area is Yola South Local Government Area of Adamawa State which lies between latitudes 9013^{o} North and 9012’ North of the equator and between longitudes 12028^{o} East and 12030’ East of the Greenwich Meridian within an area of about 1139.1 square kilometers. The dry season commences in November and ends in April; while the wet season is from May to September [16].

2.2 Field Study

Biophysical parameters of the arable lands were identified and recorded during the on-field survey. Five Representative soil samples were collected from each of the selected farm locations in the study area using auger method to a depth of 15 cm. The samples were labeled and prepared for laboratory analysis.

2.3 Laboratory Analysis

The 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 [17] Organic carbon was quantify by the Walkley–Black wet dichromate oxidation [18] 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 [19]. The soil texture class has been used to determine the permeability code of the soil and structure code described by [13] as presented below on Table 1 and 2 and Nomographic chart used in estimating the soil erodibility factor was also depicted on Fig. 1.

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

Source [19]

3. RESULTS AND DISCUSSION

3.1 Mbamba Mission Farm Location

Results on biophysical parameters of gully eroded farmlands were presented on Table 3. The results revealed that Mbamba farm location was under cultivation for the period of 5-35 years engaged in both arable and animal grazing farming systems. The vegetation is characterized with few trees and grasses and major crops grown were rice, maize and cassava as mono-cropping system respectively. In addition, information on soil properties of gully affected areas were presented on Table 4 where 65 % sand, 24% silt and 11 % clay constituted the soil texture, 1.58 g/cm^3 bulk density, 40 % porosity, 5.23 pH, 0.013 EC with OC 0.88 % and OM 1.52 % correspondingly. The soil texture was sandy loam with moderate to rapid permeability (Table 5) tends to have moderate infiltration rate and moderate run-off in the area. The soil was estimated with the values K' = 0.45 and K= 0.42 classified as high erodibility as described on Table 6. This might be attributed to low organic matter content in the soil which led to low cohesive binding between the soil aggregates thereby having more and easy susceptibility to detachment and crusting by rainfall intensity. Thus, medium textured soils (such as fine sandy loams) have moderate K values because they are moderately susceptible to detachment and run-off.

3.2 Bole I Farm Location

About 5-20 years arable farming, animal grazing and Orchards farming activities were been carried out at Bole farm location characterized with tall grasses, trees and shrubs vegetation. Farmers cultivated maize, groundnut, beans and rice in form of mixed and multiple cropping systems as depicted on Table 3 respectively. Clay soil was assessed to have dominate the area with 55 %, silt 25 % and sand 20 % having a bulk density of 1.51 g/cm^3, 37 % porosity, pH 6.23, EC 0.012, OC and OM with corresponding values of 1.22 % and 2.10 % as shown on Table 4 respectively. The textural class of the soil was estimated as clay with very slow permeability having platy soil structure (Table 5). The soil in the area was estimated with very high erodibility status (K'=0.44 and K = 0.58) as presented on Table 6. This findings might be linked to poor infiltration rate due to very slow permeability of water into the soil horizon and subsequently facilitates high runoff rate that will easily transports the detachable soil particles

.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 Blocky,	4	massive or platy	4
Slow	5		
Very slow	6		

Source: [13]

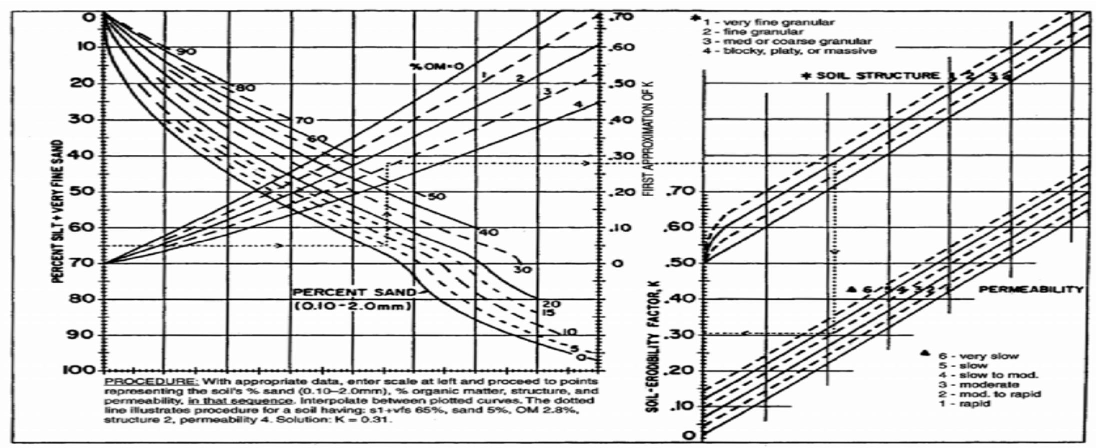

Fig. 1. Nomographic chart curve used in estimating the soil erodibility factor [15]

Table 3. Biophysical features of the selected farm location

Farm location	Estimated years of farming	Present land use	Vegetation	Major crop grown	Major Cropping system
Mbamba Mission	5-35	Arable farming and animal grazing	Few trees and grasses	Rice, maize and cassava	Mono-cropping
Mbamab Kona	5-35	Arable farming and animal grazing	Few tall trees, short grasses and shrubs	Rice, maize, beans and cassava	Mono-cropping and multiple cropping
Bole I	5-20	Arable farming, animal grazing and Orchards	Tall grasses, trees and shrubs	Maize, groundnut, beans and rice	Mono-cropping, mixed and multiple cropping
Bole II	5-15	Arable farming and animal grazing	Presence of tall trees, grasses and shrubs	Maize, groundnut, beans and rice	Mixed cropping and multiple cropping
Yolde pate	10-25	Arable farming and animal grazing	Few trees, grasses and shrubs	Maize and rice	Mono-cropping and mixed cropping
Wuro-chekke	5-15	Arable farming and irrigation/orchards	Tall grasses and few trees	Rice Sorghum and irrigation farming	Mono-cropping
Modere	5-25	Arable farming	Short grasses and shrubs	Rice, maize and beans	Mono-cropping and multiple cropping
Anguwan Tabo	5-30	Arable farming and grazing	Short grasses and shrubs	Rice, Sorghum and irrigation farming	Mono-cropping

Source: Field Survey (2019-2020)

rejuvenating gradual erosion processes. However, erodibility is low for clay-rich soils with a low shrink-swell capacity, because clay particles mass together and form large aggregates that resist detachment and transport processes. But decrease in infiltration rate due to low soil porosity will give rise to increase in run-off rate and also increase in runoff increases erosivity of soil thereby leading to rapid transportation and deposition of soil detachable particles during or after the intensive storms. Thus, channels carry water during and immediately after rains and are being further eroded in the process, thereby developing into gully with gradual time changes [20].

Table 4. Some soil properties of the selected farm locations in the area

Farm location	Sand (%)	Silt (%)	Clay (%)	Bd (g/cm^3)	Porosity (%)	pH	EC	OC (%)	OM (%)
Yolde Pate	55	25	20	1.56	43	6.12	0.014	1.08	1.86
Bole I	20	25	55	1.51	39	6.23	0.012	1.22	2.10
Wuro-chekke	10	40	50	1.50	38	5.45	0.011	1.13	1.95
Mbamba Mission	65	24	11	1.58	40	5.23	0.013	0.88	1.52
Mbamba Kona	60	23	17	1.52	38	6.33	0.014	1.12	1.92
Bole II	30	35	35	1.55	37	6.13	0.011	1.21	2.08
Modere	60	15	25	1.51	39	5.44	0.012	1.11	1.90
Anguwan Tabo	15	25	60	1.55	35	6.23	0.015	1.25	2.15

Note: BD- bulk density, EC- electric conductivity, OC- organic carbon, OM- organic matter

Table 5. Soil parameters of the selected farm location related to soil erodibility

Farm location	OM (%)	Soil textural class	Permeability code	Permeability code description	Structural code	Structural code description
Yolde Pate	1.86	Sandy-clay loam	4	moderate to slow	4	massive or platy
Wuro-chekke	1.95	Silty clay	5	Slow	4	massive or platy
Bole I	2.10	Clay	6	very slow	4	massive or platy
Bole II	2.08	Clay loam	4	Moderate to slow	4	massive or platy
Modere	1.90	Sandy clay loam	4	Moderate to slow	4	massive or platy
Anguwan Tabo	2.15	Clay	6	very slow	4	massive or platy
Mbamba Mission	1.52	Sandy loam	2	moderate to rapid	2	Fine granular
Mbamba Kona	1.92	Sandy loam	2	moderate to rapid	2	Fine granular

Table 6. Estimated soil erodibility factor (K) using USDA Nomorgraphic chart method

Farm location	First approximation of K’	Final approximation of K	Erodibility classification
Yolde pate	0.44	0.53	Very high
Wuro-chekke	0.30	0.40	High
Bole I	0.44	0.58	Very high
Bole II	0.34	0.40	High
Modere	0.53	0.62	Very high
Anguwan Tabo	0.44	0.58	Very high
Mbamba Mission	0.45	0.42	High
Mbamba Kona	0.46	0.43	High

3.3 Yolde Pate Farm Location

At Yolde Pate Farm Location cropping activities was revealed to carry out for about 5-25 % years (Table 3) where arable farming and animal grazing were dominant and the vegetation composed of few trees, grasses and shrubs. The major crops cultivated in the area were maize and rice under mono-cropping and mixed cropping systems. Soil properties of the affected farm locations were depicted on Table 4 which revealed that in the area sandy soil was dominant (55%), silt 25 % and 20 % clay. The bulk density of the soil was found to be 1.56 g/cm^3 , porosity 43 %, pH 6.12, EC 0.014 with OC 1.08 % and OM 1.86 correspondingly. Sandy-clay loam texture was dominated the area with moderate to slow permeability of water having massive or platy structure (Table 5). The erodibility status of the soil was estimated as very high with the corresponding value of K' = 0.44 and K = 0.53 as depicted on Table 6 respectively. Thus, soils with low organic matter may have high susceptibility of erodibility compared with soil with moderate to high organic matter. Organic matter in the soil reduces soil erodibility because it produces compounds that bind soil particles together and reduce the susceptibility of the soil to detachment by raindrop impact and surface run-off [15].

3.4 Wuro-Chekke Farm Location

Biophysical characteristics of gully affected farmlands were presented on Table 3. Wuro-chekke farm location was revealed to have under cultivation for about 5-15 years dominated by arable and irrigation farming activities. The area is covered with tall grasses and few trees of vegetation while the major crops grown were the rice, local sorghum known as "*MUSKUWA*" under mono-cropping system. For the soil properties of the gully affected areas were presented on Table 4 with clay 60 %, silt 25 % and sand 15 % of the soil texture, bulk density 1.50 g/cm^3, porosity 38 %, pH 5.45, EC 0.011, OC 1.13 % and OM 1.95 % respectively. Silty clay soil texture with slow permeability and massive structure were determined in the area (Table 5). The estimated erodibility factor was K' =0.30 and K = 0.40 classified as highly erodible which might be connected to the presence of silty clay particles. Hence, soils having high silt content are the most erodible of all soils as they are easily detached; tend to crust, and produce high rates of runoff.

3.5 Mbamba Kona Farm Location

Farming of arable crops and animal grazing are carried out at Mbamaba farm location while the vegetation type it composed of few tall trees, short grasses, and shrubs were carried out for 5-35 years by the dwellers in the area. The famers grown rice, maize, beans and cassava as major crops and adopting mono-cropping and multiple cropping systems as presented on Table 3. The percent sand, silt and clay was determined as 60 %, 23% and 17 % correspondingly. The bulk density was assessed as 1.52 g/cm^3, 38 % porosity, pH 6.33, EC 0.014, OC 1.12 % and 1.92 % OM content as presented on Table 4 respectively. In the farm location sandy loam was formed the main texture of the soils with moderate to rapid permeability and fine granular structure (Table 5). The erodibility factor was estimated K' =0.46 and K= 0.43 classified as highly erodible soils as shown on Table 6. This is because coarse textured soils, such as sandy soils are easily detached and transported than clayey soils despite the fact that they have low runoff due to moderate to rapid permeability status.

3.6 Bole II Farm Location

At Bole II farm location estimated years of farming experience was 5-15 years where arable farming and animal grazing were presently carry out. Presence of tall trees, grasses and shrubs constituted the vegetation of the area while maize, groundnut, beans and rice were grown majorly under mixed and multiple cropping systems as depicted on Table 3. The soil properties of 30 % sand, 35 % silt and 35 % clay, 1.55 g/ cm^3, porosity 37 %, pH 6.13, EC 0.011, OC 1.21 % and OM 2.08 % were determined as presented on Table 4. Clay loam texture was dominant type in the area having moderate to slow permeability with platy structure (table 5). The estimated erodibility status of the soil was high with the corresponding value of K'=0.34 and K = 0.43 as presented on Table 6 respectively. The high susceptibility of soil to erosion might be connected to the low porosity of the soil which leads to slow permeability and eventually developing intensive runoff on channels and drainages. Thus, according to [21] explained that, the rate of gully erosion depends primarily on the runoff producing characteristics of the watershed, the drainage area, soil characteristics and the slope in the channel.

3.7 Modere Farm Location

About 5-25 years farming activities were carried out in the area, which include arable farming and grazing activities (Table 3). Among the major crops grown are rice, maize and beans under mono-cropping and multiple cropping farming systems. The results on able 4 shows that the soil properties of the the percent of sand, silt and clay was determined with the corresponding values of 60 % , 15 % and 25 %, bulk density 1.51 g/cm^3, porosity 39% pH 0.54, EC 0.012, OC 0.11 and 1.90 OM content respectively. The soil texture was sandy clay loam characterized with moderate to low permeability and massive or platy structure as described on Table 5. In all the farm locations, Modere farm location was estimated with the highest erodibility value of K' = 0.53 and K= 0.62 classified as very highly erodible soils (Table 6). This might linked to the high content of sandy particles coupled with low OM. Therefore, the soil may have no strong binding potentials within the aggregates that will aid the resistant of the soil. Thus, organic matter increases aggregation in the soil which tends to reduce soil erosion [15].

3.8 Anguwan Tabo Farm Location

Table 3 presented the biophysical parameters of the selected farm locations in the study area. From the Table 3 Anguwan Tabo area was estimated to have 5-30 years of farming experience dominated with arable farming, irrigation and grazing activities. The vegetation of the area was comprised of short grasses and shrubs where rice and sorghum (Muskuwa) were grown under mono-cropping farming system. Table 4 portrayed the soil properties of the area where sand, silt and clay composition was assessed as 15%, 25 % and 60% correspondingly. While bulk density, 1.55 g/cm ^{3}, porosity 35 % pH 0.623, EC 0.015, OC 1.25 % and OM 2.15 respectively. Clay soil was the dominant textural type in the area with very slow permeability and platy structural type as described on Table 5. The estimated erodibility factor of the soil was K'= 0.44 and K =0.58 classified as very high erodible soil (Table 6). Despite the fact that clay soil are more resistant to detachment due to the strong aggregate binding within the colloidal particles, low permeability of water may trigger the weakening of the binding potential through excessive runoff and subsequently rejuvenate sheet to rill and rill to gully erosion processes. Permeability of the soil profile affects K because it affects runoff. Permeability and infiltration that affect runoff can be changed by plant growth and management [15]. Thus, the soil of the area possessed the lowest porosity having the value of 35 % compared with the other farm locations of the study area respectively.

Generally, this type of study represents an advance of great methodological utility because it provides an approach to study this type of topic in environments affected by soil erosion [22,23], with results that increase existing knowledge based on theoretical and statistical foundations [24]. Likewise, this methodology can be applied in other institutions, communities or organizations.

The intensity with which the different erosive processes act will depend on a set of factors. The most notable are: among which the physical characteristics of the environment should be highlighted first, mainly in terms of meteorological parameters (distribution of rainfall, intensities of rain, etc) [25,26], the type of soil and the relief of the cultivated fields [27,28]. However, as evidenced in the present research, agronomic management will play a predominant role to reduce or increase erosive effects and therefore soil degradation.

4. CONCLUSIONS

Soil as an ecosystem is faced with physical degradation at a global scale most especially in the tropical countries where erosion process appeared as the major threat affecting large proportion of arable lands. Different methods were used to estimate the erodibility status of the soil where nomographic chart method was among and widely adopted. Soil properties of the study area revealed to have high to very high susceptible to erosion which may lead to devastating effects on the arable lands and food production per unit area. Thus, It is therefore recommended that further research work should be conducted using other empirical model method in order to validate the findings obtained from this research work. Similarly, effective training on soil conservation techniques and soil erosion prevention and control should be given to the farmer population to realize healthy and sustainable soil quality for optimum food production.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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