International Journal of Agriculture Innovations and Research
Volume 7, Issue 3, ISSN (Online) 2319-1473
Manuscript Processing Details (dd/mm/yyyy):
Received: 01/12/2018 | Accepted on: 10/12/2018 | Published: 22/12/2018

Estimation of Soil Loss Rates from Rill Erosion in Biu Area, Borno State, Nigeria

Ibrahim Madu[1*] and Abubakar M. Kundiri[2]
[1*] College of Education Waka-Biu, School of Vocational Education, Department of Agricultural Education, P. M. B. 1502, Borno State, Nigeria
[2] University of Maiduguri, Faculty of Agriculture, Department of Soil Science, P. M. B. 1069, Maiduguri, Borno State, Nigeria
*Corresponding author email id: maduibrahim2011@gmail.com

Abstract **– A study on estimation of soil rates was carried out at six different locations (Kigir, Piku, Daura, Mirnga, Garwashina and Tum) in Biu Area under different soil types topography and vegetation. The objective of this paper is to assess the severity of rill erosion features in terms of soil loss rates, in Biu Area. The study was carried out on monthly and annual bases. At each location, three (3) soil samples were collected for laboratory analysis. Rill channel features (length, width, depth and slope) and conservation practices were measured at each site. Three rill erosion models namely; Measured, Empirical (conceptual), and RUSLE2, were used to measure the extent of soil loss. The water holding capacity, particle density, Ph, total nitrogen, available P, sodium, and K values were; 20.7–30.9 %, 2.30–0.55 gm^{-3}, 7.39–7.00 %, 0.22–0.10 g /kg^{-1}, 4.20–11.55 ppmm, 0.39–1.31 cmol (+) kg, and 0.64–2.94 g^{-1} cmol (+) kg, respectively. The result of measurement of soil loss on both monthly and annual bases differed with significant ($p < 0.05$) different among site. The monthly and annual mass of soil loss (MSL) was 1.400–150.810 kgha^{-1}yr^{-1}, and annual rates of empirical and RUSLE2 models revealed moderate to high reliability in prediction, with r^2 values of 0.8568 and 0.6125, respectively. Geometric mean error ratio (GMER) and geometric standard deviation of error ratio (GSDER) of empirically estimated and RUSLE2, predicted were 0.8111 and 5.9084, and 280.874 and 20.072, respectively. Empirically estimated model had GMER close to one (1) and smaller GSDER and had the highest prediction strength in the study area.**

Keywords **– Rill Erosion, Soil Organic Matter, Rainfall, Runoff, Vegetation, Particle Density.**

I. Introduction

Soil erosion is the physical movement of soil particles from one location to another primarily due to force of wind or water. The severity of erosion depends upon the quantity of soil detached and the capacity of wind or water force to transport it. On global scale water erosion is the most severe type of soil erosion [1 and 2]. Most erosion occurs during time of flood when moving water is available to convey large sediment load which causes stream and river impairment [3]. The total land area subjected to human – induced soil degradation is estimated at about 2 billion ha, out of which the land area are affected by soil degradation due to water erosion is estimated at 1100 Mha and 550 Mha due to wind erosion [4]. In Africa and South Asia erosion rates ranged from 30 and 40 Mgha^{-1}yr^{-1}, respectively [6]. Precisely, Nigeria with a land area of 910,771 km^2 out of which 37.33% is currently put under arable agriculture with permanent crops and other is occupying 3.14 and 59.53 %, respectively, are largely affected by water erosion [6, 7 and 8]. The factors influencing rill erosion are climate, soil, topography, vegetation and land use [9].

Biu lies on the Biu Plateau at an average elevation of 768 m above sea level. The region is semi – Arid, the Local Government Area (LGA) is mostly located in the Northern Guinea Savannah (NGA) agro ecological zone, with small portion in the North East, Kimba area lies in the drier Sudan savannah zone [11]. Soil loss caused by erosion on farmlands in Biu and Sade towns both in Borno and Bauchi States of North Eastern Nigeria ranged from 1000 and 31000 tones ha^{-1}yr^{-1} [12, 13]. Despite the rill erosion problem, there is still lack of information on the scale and magnitude of the scourge in Biu and therefore the need to design appropriate management techniques in order to reduced rill erosion progress on farmlands. The present research is expected to provide necessary information on the extents, measures and direction for prospective users including governmental agencies and a number of policy makers on their effort to manage erosion problems in the area.

II. Materials and Methods

2.1 *Field Study*

Soil sampling was conducted at six sites (Kigir, Piku, Daura, Mirnga, Garwashina and Tum). Large plot or watershed with the size of 100 m^2 [16], was selected at random and three soil samples were collected for laboratory analysis. Also, in the watershed selected, rill erosion features were measured in terms of length, depth and width. Eighteen composite soil samples were collected for one growing season (2015), using bucket auger. Each soil sample was collected when moist in a new well labelled Polyethene bag. The samples were air – dried, ground and sieved through a 2 mm sieve then prepared and analysed for some physical and chemical parameters that relates to soil erosion. Soil infiltration rates were measured by double ring infiltrometers [17].

The erodibility index for each rill channel site was computed in accordance with the corresponding erodibility factor units (k – value) for tropical soils describe by [18]. Slope length was measured in metres and steepness was measured using Theodellite. The length was measured in metres and the steepness in percentage. Cover and management factor (C) was measured using [19] method. Support practice factor was also measured by [19] method. The rainfall data used was 10 years – 24 hr rainfall amount and was collected using rain gauge devise for all rainfall events during the study period. The amount of rainfall received using a rain gauge between 9.00 am (the first day) and 9.00 am (the next day), totalling 24 hrs duration having a 10 years return period. To determine the runoff factor (R) [19, 40] models were used. The models are as follows;

1. $R = P \times 0.5$ [20]
2. $E(KE > 25) = 9.28P - 8838$ [21]
3. $EI_{30} = 0.276P \times I_{30}$ [23]

2.2 *Laboratory Study*

2.2.1 *Determination of Soil Physical Properties*

The determination of soil physical properties was conducted in the laboratory following standard procedures. The particle size distribution was determi- -ned by Bouyoucous hydrometer method [24]. The bulk density (B_d) was determined by Cloud method [25], while the water holding capacity was measured by gravimetric water content of a given quantity of soil fully saturated with water [24]. The Atterberg limits composed liquid and plastic limits. Both properties were determined. The soil liquid limit was determined using cone penetrometer method (BS 1377 part 2; 1990: 4:3) while the plastic limit was studied using a one cone point penetrometer method as describe by [41]. The soil shear strength was measured by [41]. The permeability coefficient was determined in the laboratory using the rating head permeability text as outlined by [41].

2.2.2 *Determination of Soil Chemical Properties*

The soil p H was measured in a 1: 2: 5 soils: water suspension ratio using a glass electrode, Ph metre (model 5), inserted in to the suspension and left for one hour, until equilibrium was reached for one hour with occasional stirring [25]. The electrical conducti- -vity (EC) was determined on a saturation paste using an EC meter. The organic carbon (OC) content was determined potassium dichromate wet – oxidation method of [27]. The organic carbon content was converted to organic matter (OM) by multiplying with a factor of 1.724. Total N was determined by Khjeldahl method. While the available phosphorus (P) by Bray 1, method [28]. The exchangeable potassium (K) and sodium (Na) were determined by Flame photometry [29]. The exchangeable calcium (Ca) and magnesium (Mg) were determined by titrimetric method. While the total exchangeable bases (TEB), was computed as a summation of exchangeable bases.

2.3 *Soil Loss Estimation*

Three (3) soil loss estimation models were used at each site. The models are as follows; Measured estimated, empirically estimated and RUSLE2, Predicted.

2.3.1 *Measured Estimated Model*

At each six (6) rill erosion sites, measured estimate- -d model was tried to measure the length, width, and depth of rill erosion feature.

Total VSL = net VSL (rill cone shape) + net VSL (rill cylinder shape)

Mass of soil loss = Total volume of soil loss (VSL) x soil $\mathbf{B_d}$

Where: B_d = soil bulk density

2.3.2 *Empirically Estimated Model (Conceptual Model)*

Soil loss estimate was performed using separate analysis of multiple linear regressions of mass of soil loss against selected fourteen (14) rill erosion predictor variable (soil bulk density, clay factor, soil calcium, soil sodium, support practice factor, soil erodibility, soil plastic limit, slope rating, temperature of the study area, soil infiltration, and rainfall and runoff factor, soil shear strength, and soil organic matter. The resultant coefficient of determination (r^2) of the predictor variables were used to show the relative inputs on soil loss. The multiple linear regression equation is given as:

$$Y = \alpha + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \text{...........} + \beta_{14}X_{14}$$

Where:
Y = estimate of soil loss
α and β = regression parameters
X = soil erosion predictor variable

2.3.3 *RUSLE 2, (2008) Predicted model*

Version 2, of the Revised Universal Soil Loss Equation (RUSLE2) (2008), estimates soil loss from rill erosion caused by rainfall and its associated overland flow, it can be used on cropland and other areas where mineral soil is exposed to raindrop impact and surface overland flow produced by rainfall intensity exceeding infiltration rate (that is Hortonian overland flow) [9,10]. The model is as follows;

$$a_i = r_i\, k_i\, lS\, c_i\, p_i \quad [9]$$

Where;
a_i = Long – term average soil loss for ith day.
ri = Erosivity factor.
ki = Soil erodibility factor.
l = Slope length factor.
S = Slope steepness factor.
Ci = Cover and management factor.
Pi = Support practice factor.

2.4 *Data Analysis*

The data generated were subjected to Geometric mean error ratio (GMER) and Geometric standard deviation of error ratio (GSDER), using generalised linear model of statistix 10, and statistical package version 10, (2013). Statistically different means at $p < 0.05$ were separated using SE and SLD. The soil loss trend showed monthly increase and decrease in values over the seven months period. The model performances were validated both monthly and annually at locational basis.

III. Result and Discursions

3.1 *Physical Properties of Soils of the Study Area*

Table 1, shows the physical properties of soils of the

International Journal of Agriculture Innovations and Research
Volume 7, Issue 3, ISSN (Online) 2319-1473

study area. Soil texture of Piku and Tum sites were both loam and that of Kigir and Garwashina have clay loam, the result did not show significant difference in particle density (2.30 – 2.55 mg/m^3). While the loam and sandy clay varies in all sites. Water holding capacity of all sites ranged from 20.70 – 31.50 %, respectively, thus showed significant ($p > 0.05$). Soil permeability coefficient ranged from 2.2 x 10^{-10} – 2.8 x 10^{-7} k. While the permeability of clay varies from low to very low to impermeable in the study sites. Topography of Kigir, Daura, and Garwashina sites is mountainous, while that of Mirnga and Tum is hilly, and Piku has steep slope. All the sites were cultivated with corn and groundnut.

Table 1. Physical Properties of Soil of the Study Area.

Site	Soil PD (g/cm^3)	Texture	Water HC (%)	Soil PC (K)	Perm. Class.	Topography
Kigir	2.51	CL	30.90	2.5 x 10^{-10}	Impermeable	Mountainous
Piku	2.51	L	24.50	2.8 x 10^{-7}	Low to v. L	Steep
Daura	2.53	SL	20.70	2.2 x 10^{-10}	Low to v. L	Mountainous
Mirnga	2.55	SCL	27.30	2.6 x 10^{-6}	Low	Hilly
Garwa	2.30	CL	31.50	2.3 x 10^{-10}	Impermeable	Mountainous
Tum	2.51	L	25.60	2.8 x 10^{-7}	Low to v. L	Hilly
SE $_{+/- 0.05}$	**0.09 ns**		**2.012**			

Key: CL = Clay loam, L = Loam, SCL = Sandy clay loam, ns = not significant ($p < 0.05$), SE = standard error, Soil PD = Soil particle density, Water HC = Water holding capacity, Soil PC = Soil permeability classification, Garwa. = Garwashina. V.L = very low

3.2 *Chemical Properties of Soil of the Study Area*

The mean soil chemical properties (Table 2), shows the soil p H which ranged from 7.28 – 7.96. Soil reaction was higher at Piku and Kigir site. The soil electrical conductivity (EC), ranged from 0.03 – 0.04 dSM^{-1}, which was relatively higher at Piku, Mirnga, Garwashina and Tum, respectively, Compared to other sites which had relatively low salt concentration. Soil organic matter was generally high ranging from (2.34 – 6.57 %), with the higher rate at Piku followed by Tum and Mirnga sites. The total nitrogen varies among sites with a low ranging estimate of 0.04 – 0.83 %, which average was higher at Daura than Garwashina followed by Tum sites. The available phosphorus (P) varies between moderate and high (4.20 – 21.70 ppm) with significant difference ($p < 0.05$) among sites. The basic cations (K, Ca, Mg, and Na differ ($p < 0.05$) in the study sites. The exchangeable K (0.64 – 2.94) cmol (+)/kg, was consistently low to very low, while Ca (3.80 – 16.4 cmol (+)/kg) and Na (0.60 – 2.80 cmol (+)/kg) saturation. The total exchangeable bases (TEB) average between 7.00 – 20.78 cmol (+)/kg, in all the sites Piku compared higher in organic matter (OM), followed by Tum site in the study area. The stability of soil aggregate increases with increase in organic matter content, the high macro porosity and permeability of these aggregate decreases runoff and soil erosion rate [2]. Kigir site with comparable moderate estimate of OM, N, P, Na, Mg, and TEB, which are widely reported as erosion mitigators in most environments, this concurs with the report of [31], that organic matter, nitrogen, phosphorus and calcium are soil erosion mitigators.

Table 2. Chemical Properties of Soil of the Study Area.

Chemical property	Kigir	Piku	Daura	Mirnga	Garwash	Tum
Soil p H (1:2:5,soil H_2O)	7.81	7.96	7.28	7.42	7.39	7.43
EC (dSM^{-1})	0.03	0.04	0.03	0.04	0.04	0.04
Organic matter (%)	2.34	6.57	2.91	3.48	3.07	6.22
Total Nitrogen (%)	0.04	0.07	0.83	0.10	0.24	0.22
Exch. Phos. (ppm)	4.20	4.55	21.70	6.55	8.05	11.55
Exch. K (cmol(+)/kg)	1.05	0.64	2.94	0.67	0.97	0.95
Exch. Ca (cmol(+)/kg)	16.4	6.20	5.60	6.00	9.80	3.80
Exch. Mg(cmol(+)/kg)	2.20	1.60	1.00	0.60	2.80	1.60
Exch. Na (cmol(+)/kg)	1.13	1.74	0.78	0.57	0.39	0.65
TEB (cmol(+)/kg)	20.78	10.18	10.32	7.84	13.96	7.00
SE $_{+/- 0.05}$	**2.3063**	**1.3523**	**1.0435**	**2.0479**	**1.5296**	**1.2410**

Key: EC = Electrical conductivity, Phos. = phosphorus, K = potassium, Ca = calcium, Mg = magnesium, Na = sodium, TEB = total exchangeable bases.

3.3 *Erosivity Distribution based on 10 yr – 24 hr Precipitation and Runoff in the Study Area*

Table 2, shows annual precipitation, rainfall and runoff factor and temperature of the various sites based on 10 yr – 24 hr precipitation in the study area. Daura site with high annual precipitation has high runoff factor, high erosivity and temperature has high risk of erosion than Piku, Kigir, Garwashina, Mirnga and Tum sites. Precipitation, runoff factor and erosivity are significant at ($p < 0.05$). The average annual erosivity (R) is an index of erosivity at a location. This showed that most of the rill and interill erosion were caused by moderate to high rainfall conditions that was why the 10 yr – 24 hr precipitation was chosen for calculation of runoff [1, 9]. Intensity is the most important rainfall property, which determines the amount of erosion in a specific location. Combination of high amount of rainfall with high intensity produces high erosion risk [2].

International Journal of Agriculture Innovations and Research
Volume 7, Issue 3, ISSN (Online) 2319-1473

Table 3. Annual precipitation, Runoff Factor and Temperature based on 10 yr – 24 hr Precipitation in the Study Area.

Study site	Annual Precip. (mm)	Rainfall and runoff factor (mm)	Average temp. (^oC)	Erosivity (EI_{30}) ($MJmmha^{-1}hr^{-1}$)
Kigir	784.90	327.00	27	726
Piku	796.82	346.52	28	730
Daura	827.66	396.87	30	780
Mirnga	712.82	299.80	29	710
Garwa.	752.81	310.82	31	715
Tum	697.56	289.12	32	701
SE $_{+/- 0.05}$	**20.578**	**16.009**	0.763ns	11.44

Key: EI_{30} = Energy x 30 minutes intensity rainfall.

3.4 *Soil Erodibility, Runoff, Canopy Cover and T – Values of the Study Area*

The results in Table 1 and 3, shows data on soil erodibility, T–values, soil textural class and vegetation of the study area. Daura site has high erodibility (K) followed by Piku, Tum, Kigir, Garwashina and Mirnga with the values of 0.39, 0.29, 0.21, 0.81 and 0.13. Erodibility defines the resistance of soil to both detachment and transport. Mirnga site depicted high sand with low K value, though the soil was easily detached. Daura location has high silt content and high K value was susceptible to erosion (rill erosion). Tum and Piku sites showed loam soil, had moderate K value and were moderate in terms of detachment of soil. This observation concurs with the report of [22, 33 and 9], that fine textured soil high in clay has low K values, because they are resistant to detachment, and coarse textured soil, such as sandy soil has low k values. Soil with high silt content is susceptible to erosion and has high K value. Piku site had the highest infiltration rate followed by Mirnga, Tum, Kigir, Garwashina, and Daura sites with the values of 14.856, 12.556, 12,167, 7.973, 6.516, and 1.658 $mmhr^{-1}$, respectively. Piku with high infiltration rate had low runoff and erosion while Daura had low infiltration rate and silt content with the highest runoff and erosion in the study area. This observation agrees with that of [33, 2], that runoff occurs when the rate of applied surface water from rain or irrigation exceeds the water infiltration capacity of the soil. The highest canopy cover was recorded at 90 followed by 60, 45, 75, 45, and 15 days respectively (Table 5). Canopy cover is a measure of the fraction of the soil surface covered by vegetation. This showed that, when the canopy cover was less erosion rates used to be high and it decreases with increase in canopy cover. This concurs with the report of [2], that the magnitude of canopy cover determines the proportion of raindrops intercepted by the canopy. Slope length ranged from moderate to high, while percentage of slope steepness ranked high in terms of soil loss, across sites. Erosion occurred at all the sites because the percentage slope steepness was above 5 %. This observation agrees with that of [41] that percentage slope steepness less than 5 % erosion hazard is negligible. All the sites had soil tolerance value of 3.0 $tha^{-1}yr^{-1}$ which is the amount of soil loss in tons per hectare that is acceptable to maintain long – term productivity [9]. The support practice factor depicted high and low values which caused deposition of sediment close to the sources [34].

Table 4. Soil Erodibility, T – Value, Infiltration rates, Slope length and Steepness and Support practice factor of the study area.

Study site	Erod. (K)	T- Value ($tha^{-1}yr^{-1}$)	Infil. Rates (mmh^{-1})	Slope length (m)	% slope steep.	Support Prac. Fac.
Kigir	0.21	3.0	7.973	650	12.0	0.2
Piku	0.29	3.0	14.850	330	12.0	1.0
Mirnga	0.13	3.0	1.658	1050	10.5	1.0
Tum	0.29	3.0	12.556	550	10.5	0.5
Garwa.	0.18	3.0	6.516	850	12.5	0.5
Daura	0.39	3.0	12.167	300	10.5	1.0
SE $_{+/- 0.05}$	0.04	0.0	**1.980**	11.97	0.34	0.112ns

Key: Erod. = soil erodibility, Infil. = infiltration rates, slope steep. = slope steepness.

Table 5. Vegetation of the Study Area.

Vegetation	
Days	Canopy Cover
0	
15	0.039
30	44.82
45	54.80
60	100
75	32.48
90	100

Source: (Based on field Data 2016).

3.5 *Mass of Soil Loss (MSL) Empirically Estimated Model*

The selected independent variables were regressed against measured mass of soil loss as the dependent variables for the empirically estimated model to be developed. The model is shown below;

$$Y_{MSL} = 92.62 - 20.70(B_d) - 22.90(clay) + 4370(ER) + 2431(PL) - 68.42(OM) - 6990(sh) + 2455(SR) - 2460(CM) - 62.10(SP) - 2450(SK) + 22.70(SN) - 22.78(ST) - 1266(RN) + 58.20(FL); r^2 = 0.7425$$

International Journal of Agriculture Innovations and Research
Volume 7, Issue 3, ISSN (Online) 2319-1473

Where;

Y_{MSL} = Predicted mass of soil loss
ST = Temperature of the study area
CM = Cover and management factor
SP = Support practice factor
SK = Soil calcium
SN = Soil sodium
B_d = Bulk density
Clay = Clay content
ER = Erodibility index
PL = Plastic limits
OM = Organic matter
Sh = Soil shear strength
SR = Slope rating
RN = Rainfall and runoff factor
FL = Infiltration rate of soil
r^2 = Coefficient of determination

The fourteen (14) rill erosion predictor variables had both mitigatory and facilitatory contributions to soil loss at different sites in one year study. The organic matter content was the major deterrent of soil erosion and which mitigate or reduced the mass of soil loss (MSL) estimate by 254.69 $kgha^{-1}yr^{-1}$, respectively. That is to say the organic matter content reduce the soil loss at a higher rate than shear strength [1, 20], reported that similar importance of organic matter content, shear strength, and bulk density.

3.6 *Monthly Measurement of Soil Loss in the Study Area*

Table 5, present the result of monthly measurement of mass of soil loss estimates value which was 10.210 – 99.750 $kgha^{-1}yr^{-1}$, respectively in 2016. It generally expressed significantly ($p < 0.05$) higher erosion loss at Kigir, Piku, and Daura sites between June and August when rainfall amounts were higher in the study area. [35, 36, and 37], reported similar influence of rainfall on erosion activities on watersheds.

Table 5. Mean value of empirically estimated mass of soil loss in the study area.

Study site	Kigir	Piku	Daura	Mirnga	Garwashina	Tum
Mass of Soil Loss ($kgha^{-1}yr^{-1}$)						
April	15.22^{Y}	1.44^{I}	135.71^{c}	5.30^{f}	3.93^{h}	1.85^{I}
May	45.38^{N}	8.67^{c}	145.82^{B}	9.87^{b}	30.55^{Q}	8.37^{d}
June	132.57^{b}	20.99^{u}	81.22^{I}	20.75^{v}	49.82^{m}	25.17^{T}
July	150.28^{A}	110.86^{F}	99.75^{G}	118.82^{c}	75.22^{I}	75.23^{I}
Aug.	88.11^{N}	30.67^{a}	33.97^{O}	66.18^{k}	20.11^{w}	20.11^{w}
Sept.	33.37^{p}	15.87^{x}	50.27^{L}	26.83^{Y}	15.23^{Y}	7.81^{e}
Oct.	15.87^{x}	10.95^{z}	29.25^{R}	4.99^{g}	10.21^{a}	5.30^{Y}
SE $_{+/- 0.05}$	**6.85****					

Source: (Based on Field Data 2016).

3,7 *Means of Annual Mass of Soil Loss (MSL) Estimated using Measured, Empirical, and RUSLE2, (2008) Models in the Study Sites*

The Measured Estimated, Empirically Estimated, and RUSLE2, (2008) Predicted are presented in Table 6. Empirically Estimated model showed geometric mean error ratio (GMER) close to one, and smaller geometric standard deviation of error ratio (GSDER). Model with a GMER closed to one, and smaller GSDER used to be the best model in terms of prediction strength [39]. Empirically Estimated Model had higher prediction strength than RUSLE2, and Measured Estimated Models. The higher prediction strength of the Empirically Estimated Model was because it has no depth of soil restriction in terms of application. While, while RUSLE2, Predicted has restricted depth of soil application (30 cm), and it was designed in the United States of America [9, 10].

Table 6. Means of Annual Mass of Soil Loss estimated using Measured, Empirically Estimated, and RUSLE2, (2008) Predicted Models in the study sites.

Study Site	Measured Estimated	Empirically Estimated	RUSLE2,Predicted
	($Kgha^{-1}yr^{-1}$)		
Kigir	156.20	480.80	207.14
Piku	129.37	199.45	248.96
Daura	189.27	575.99	248.68
Mirnga	200.15	252.74	243.02
Garwashina	250.17	205.07	351.85
Tum	270.67	143.84	240.40
GMER	**0.51**	**0.99**	**2.07**
GSDER	**10.79**	**5.91**	**49.17**

Key: GMER = Geometric Mean Error ratio, GSDER = Geometric Standard Deviation of Error ratio.

IV. Conclusion

The extent of rill erosion was quantified using measured estimated, empirically estimated and RUSLE2, (2008) predicted techniques under same condition of Biu environment. The pattern, rate and estimate of mass of soil loss confined to rainfall amount as the season progressed to a peak in month of July and therefore declined with cessation of rainfall in October in the study area. The empirical model was developed for prediction of soil loss from multiple regression analysis between fourteen (14) selected erosion predictor variable. Rill erosion was significantly ($p < 0.05$) higher at Kigir, Tum, Daura and Garwashina while it was low at Piku location in this study.

Acknowledgement

The authors would like to express to Nigeria's Tertiary Education Trust Fund (TETFund), through College of Education Waka – Biu, School of Vocational Education for funding the research, and much needed time and support for the field experiments. Further acknowledgement goes to the University of Maiduguri, Faculty of Agriculture and Soil Science Department for physio – chemical analysis in the laboratory.

Reference

[1] R.P.C. Morgan (1986). Soil Erosion and Conservation Longman Scientific and Tech. Published in the United States, John Wiley and Sons Inc. New York. Pp. 35.

[2] H. Blanco and Ratan L. (2008). Principles of Soil Conservation and Management, spring. Scientific Business Media the Ohio State University, Columbia, Ohio U.S.A Kansas, State, University Hys. KS U.S.A.

[3] A. McCauley and C. Jones (2005). Management for Soil Erosion; soil and water man. Module 3. Agric. Extension Communication coordination service. 416; Culbertson hall, Montana State, University Bose man Mt 59717; (994 – 2721).

[4] R. Lal (2001). Soil degradation by erosion, Land Degradation and development 12: 519 - 539, John Wiley and sons Ltd. U.S.A.

[5] D. Pimental (2006). Soil erosion; A food and Environmental Threat. *Environ. Develop. Sons, 8; 119 – 137.*

[6] R. Lal (1995). Erosion Crop Production relationship for the soils of Africa. *Soil Science Society of America Journal 559; 661 – 7.*

[7] World Bank Report (2010). Land Area in Nigeria. Also found at www.infophase.com/Ipa /A0107847html.

[8] Central Intelligence Agency (CIA) (2012). Brief note on Nigeria also found at gridnairobi.unep.org /,/Nigeria – doc.

[9] USDA – ARS (2008). User Reference Guide, RUSLE2, Washington DC.

[10] USDA – NCRS (2008). Soil Conservation Service and Reference Service, USDA – Bureau of Land Management, and US Army Corps or engineers.

[11] P. S. Amaza (2007). Baseline Socio – economic Survey report of Agriculture, Borno State, Nigeria. International Institute of Tropical Agriculture 11.

[12] G. Rottenburry, J. R. Rickson and R. Goss (1999). Gully erosion in Bedfordshire, freak Weather on farming practice? Paper presented at the 4th Benelux Catholic University of Leaven.

[13] E. I. Ekwue, and Y.T. Tashingwa (1993).Survey of Gully Erosion Features in Mubi Local Government Area, Adamawa State. Journal of Annals of Borno vol. 8/9 University of Maiduguri, Borno State. Pp. 181 – 191.

[14] Biu Ministry of Agriculture and Natural Resources (MANR) (2010).

[15] B. Usman (2015). A history of Biu, BIU Emirate Studies Series (BESS 003) Published by Klamidus Communications Ltd Sinti BO4 Peak Plaza, Jabi Expressway, Utako Distric Abuja, Nigeria. Pp. 27 – 28.

[16] M. J. Shipitalo and W. M. Edwards (1998). Runoff and erosion control with conservat. Tillage and reduced input practices on crop watersheds soil tillage Res. 46: 1 – 2.

[17] C.Y. Everts and R. S. Kenwar (1992). Interpreting tension infiltration data for qualifyin. Soil macropores; some practical considerations Trans. ASAE 36: 423 – 428.

[18] J. S. K. Mitchell and G. D. Budnezer (1993), Fundamental of soil behaviour (2nd eds). John Wiley. New York.

[19] W. H. Wishmeir and D. D. Smith (1978). Predicting rainfall losses USDA – Agric. Res. Ser. Handbook 537.

[20] E. J. Roose (1975a). Erosion et ruissettement en Afrique de louses vingr (and runoff in Africa from louses vingr). Annees de Measures en pentiles percelles experimentdles cyclo (Measurement years in pentile percels experimentdles cyclo). ORSTOM. A diopodouine: Ivory Coast.

[21] R. P. C. Morgan (1974). Estimating regional variation in soil erosion hazard *in Peninsul. Malaysia Malay: Nat. J. 28: 94 – 106.*

[22] R.P.C. Morgan (1995). Soil erosion and conservation, 2nd edition Longman scientific and Technical Published in the United States with John Wiley and sons Inc. New York. Pp. 3 – 12.

[23] G.R. Foster, L. J. Lane, J. D. Newton, J. M. Laflen and R. A. Young (1981). Estimating c Erosion and Sediment Yield on field – sized areas *Trans. Am. Soc. Agric. Engnrs: 24: 1253 – 63.*

[24] T.T. Trout, I. G. Garcia – Castilas and W. E. Hart (1987). Soil water engineering field & Laboratory manual m/s Eurasia: New Delhi, India.

[25] B. Wolf (2003). Diagnostic technique for improving crop production. Haworth Press U. S. A.

[26] K.M. Head (1992). Manual of soil laboratory testing vol. 1: soil classification and Compaction tests. Partech press London Pp. 119 – 158.

[27] A. Walkley and C. Blank (1934). Chronic acid titration method for determining soil Organic matter*: Soil science society of America, Journal 37: 29.*

[28] R.H. Bray and L.T. Kurtz (1945). Determination of total organic carbon and available Forms of phosphorus in soils: *soil science society of America Journal 59: 39 – 45.*

[29] M.L. Jackson (1965). Soil chemical analysis practice Hall, New York, U. S., A.

[30] E.J. Murray, R.H. Jones, and D. W. Rix (1997). Relative Importance of factors Influencing the permeability of clay soil. Geoenvironmental Engineering Thomas Tedford, London.

[31] J. Poessen and G. Govers (1990). Gully erosion in the loam belt of Belgium typology & control measure, in Bourdman J. , Foster, I. D. I. & Nearing J. A. (eds) Pp. 513 – 530.

[32] I. B. I. Tarensenko (1981). Increasing fertility of the soils of Cuba Book publisher Kraasonodar, USSR, Pp. 189.

[33] T. D. Biswas and S. K. Murkherjee (2008). Text Book of Soil Science 2nd edition, pub. by the Tata McGraw – Hill publishing company Limited 7 West Petel Nagar, New Delhi 110 and printed at puship print services Jaypur, Delhi. Pp. 340.

[34] Ontario Ministry of Agriculture, food and Rural Affairs (OMAFRA) (2002). Universal Soil Loss Equation (USLE) FACTSHEET, written by Robert P. Stone – Engineer Soil Management/OMAFRA Don Hill borne Engineer: By product management.

[35] K. Vandale (1993). Assessment of factors affecting ephemeral gully erosion in cultivated Catchments of the Belgur loess Belt form land erosion in template plains: Environment Hills – Elsevier, Pp. 125 – 136.

[36] R. I. Wasson, I. J. Olive and C. J. Roswell (1996). Ralies of erosion and sediment transp. on Australis in Walling D and Webk B (eds), erosion and sediment yields Global and Regional perspectives. I. A. TTS, publication 236; 130 – 184.

[37] M. C. Masiyandima (2000). The hydrology of small agricultural watersheds in the Guinea Savannah zone of West Africa. Ph.D Thesis, Cornell University Ithaca.

[38] M. Nasiri, S. Feiznia, M. Jafari and H. Ahmadu (2008). Using field indixes of soil and Gully in order for erosion estimating and sediment analysis (case study: Manderian water Shed in Isfahan Province, Iran) *World Academy of science, Engineering and Technology 43: 370 – 376.*

[39] K. M. Wolter (1985). Introduction to Variance Estimation, New York Spriger – Verlag.

[40] W. H. Wishmeir and D. D. Smith (1958). Rainfall energy and its relationship to soil loss *Trans. Am. Geophysics UN. 39: 285 – 91.*

[41] P. Stefanovit and G. Y. Varallyay (1992). State and Measurement of Soil in Hungary - in proceeding of the soil erosion and Remediation workshop. US Central and Eastern European Agro – Environmental Program. Budapest, April 27 – May 1st 1992. Budapest Pp. 79 – 95.

[42] J. Krisztian (1998). Telajverdelen (Soil Conservation) – GAFE Merogazdasa Foiskolain, Kar, Gyongyos.

[43] K. O. Adekalu, Okunde, D. A. & Osubitan J. A. (2007). Estimating traficability of three Nigerian agricultural soils from shear strength – density – moisture relation. *International Agrophysics. Vol. 21: 1 – 5.*

AUTHORS PROFILE'

Ibrahim Madu was Born in Biu in 1968, he began his early education that is primary education from 1977-1983, and secondary education from 1983-1989. He attended University of Maiduguri from 1990-1997 and obtained BSc Agricultural and Msc Still in the same School in Soil and Water Management in 2016. He also obtained Post Gradu--ate Diploma in Education PGDE in Ramat Polytechnic Maiduguri in 2006. He also worked with Quarts Chemical and Fertilizer company Biu, which was subsidiary of quarts technology ventures, Wuse zone II Abuja, Nigeria. Currently a Senior Lecturer in Agric Education Department in College of Education Waka-Biu, School of vocational and technical Education. Phone No. 08039657666

Abubakar M. Kundiri
Professor of Soil and Water Management, and a Lecturer at University of Maiduguri, Faculty of Agriculture, Department of Soil Science, P. M. B. 1069, Maiduguri, Borno State, Nigeria.