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Estimation of Soil and Nutrient Loss Rates from Rill Erosion in Biu Town, Borno State, Nigeria

Ibrahim Madu
College of Education Waka - Biu, School of Vocational Education, Department of Agriculture Education,
P.M.B. 1502, Waka – Biu, Borno State, Nigeria.
Corresponding author email id: maduibrahim2011@gmail.com

***Abstract* – The loss of soil from land surfaces by erosion is widespread and reduces productivity of agricultural lands. Concurrently due to increasing human population, agricultural land expansion and exploitation, soil and nutrients (Nitrogen, Phosphorus, Potassium, Magnesium, Calcium and Sulphur) losses are the major environmental problem in Biu. This study was conducted to estimate annual losses of soil and nutrient due to rill erosion. There are six sites (Kigir 1, Kigir 2, Dam 1, Dam 2, Piku 1, and Piku 2) for this study. Consequently, the crop land was delineated to estimate soil and nutrient loss. At each site, six hectares of land were selected at random and one (1) soil sample was collected at crest, shoulder, backslope and fore slope in each hectare, making a total of 24 samples per site. The total number of samples (6 x24) is 144 for the six sites. Soil nutrient content was determined for the various sites. At each site a transect of 200 m by 100 m was selected at random and rill erosion features was observed along the corridors, in terms of length, depth and width. Physical and chemical properties of the soil samples collected were determined in the field and in the laboratory following standard procedures. The annual precipitation varied from 698 - 897.00mm, rainfall and runoff factor ranges from 447.57 - 536.43mm and erosivity ranged from 355.00 - 486.00 MJmmha^{-1} yr^{-1}, respectively, across sites. Regression analysis was performed on some of the data in order to determine the relationship between dependent variable (outcome) and independent variable (predictors). Conceptual model that explains the rill erosion mechanics and theoretical framework of Revised Universal Soil Loss Equation version 2 (RUSLE2), was developed and tried in this work. The soil loss was quantified using field erosion measured soil loss. Developed empirical predictor model and RUSLE2, in this study. Soil loss varied from 395.72 - 629.53 kgha^{-1}yr^{-1} across sites. The data generated was subjected to generalized linear model using statistix 10. Statistically different means at (p<0.05) was separated using standard error (SE). The losses of organic matter ranged from 1.85 - 3.88kgha^{-1}yr^{-1},nitrogen varied from 1.04 - 2.26kgha^{-1}yr^{-1}, phophorus ranged from 107 - 1.99kgha^{-1}yr^{-1}, potassium varied from 1.12 - 2.78kgha^{-1}yr^{-1}, calcium ranged from 1.19 - 2.48kgha^{-1}yr^{-1}, magnesium varied from 1.13 - 1.92kgha^{-1}yr^{-1} and Sulphur ranged from 1.04 - 1, 94kgha^{-1}yr^{-1}, respectively. Water erosion in the form of rill erosion is severely affecting soil fertility management and crop production in the study watershed. Hence, effective integrated watershed management interventions and farmland management could combat soil erosion.**

***Keywords* – Soil Erosion, Nutrient Loss, Precipitation, Erosivity, Erodibility, RUSLE2, Models, Sponsored by TET Fund.**

I. INTRODUCTION

Soil erosion is the detachment, movement and removal of soil from the land surface by precipitation leaving the landscape as runoff. Degradation of agricultural land by soil erosion is a world-wide phenomenon leading to the loss of nutrients rich surface soil, increased runoff from more impermeable surface subsoil and decrease water availability to plants (Vipul et al., 2010, Gelder et al., 2017, Orgiazi and Paragos, 2018, Ahmed et al., 2020 and Stefinidis et al., 2022). Water erosion causes series of on - site as well as off- site damages on natural ecosystems. These damages include soil and nutrient loss and finally loss of productivity which causes cost to the society (Shafagh et al., 2015). Considering that soil of highlands is generally shallow and their fertility is often concentrated in the upper most layers, soil erosion represents a crucial problem affecting the landscape at different scales and is a serious challenge for land management and soil conservation (Garcia - Ruiz and Lare Renault, 2011, Angasi et al., 2014).

Among the form of water erosion (sheet, inter rill, rill, gully, ephemeral gully and stream bank), rill erosion remains the main cause of concern, since it contributes significantly to water and soil loss (high sediments concentration). Thus, removing organic matter and nutrients (N, P, K, Ca, Mg, and S), that are essential for agricultural production on sloping land. Rill erosion is a precursor of gully erosion. Rill erosion mainly occurs as a result of concentrated overland flow of water leading to the development of small well-defined channels (Halle et al; 2012; Huang et al., 2015). The factors influencing rill erosion are rainfall intensity, topography, soil properties, vegetation, protection and management factor (Defershal et al., 2011). In sloping land, soil and nutrients (N, P, K) losses were in the order of 4.451kgha^{-1}yr^{-1} and 10.71 - 11.26, 0.56 - 0.64, 0.98 - 1.11 kgha^{-1}yr^{-1}, respectively (Allincal et al., 2011). In USA, Europe and India, soil loss recorded in the order of 8.84 tha^{-1}yr^{-1}, 150 and130 Mtha^{-1}, respectively. In Iran and Uganda, soil and nutrient losses were estimated to be 27.44tha^{-1}yr^{-1}, 114.20 kgha^{-1}yr^{-1} and 114.8tha^{-1}yr^{-1}, respectively (Abdulrahman et al., 2015, and Rastagar et al., 2015). Water erosion has been reckoned as one of the major factors that largely deprived agriculture of significant area of cultivable lands in Nigeria, which has a land area of 910,771 km^2 of which 37.33% is currently put under agriculture within permanent crops and others are occupying 3.14 and 59,53, respectively, are largely affected by water erosion than wind erosion, with menace more pronounce in the Southern part compared to than northern part, as a result of regional precipitation (amount and intensity and soil type) (World Bank Report 2010).

Numerous erosion models such as Universal Soil Erosion Equation (USLE), (Washier and Smith, 1958), Revised Universal Soil Loss Equation (RUSLE) (Renard et al., 1997), Modified Universal Soil Loss Equation (MUSLE) (William, 1975), Morgan, Morgan and Finney Method (MMF) (Morgan et al., 1985) can predict soil and nutrient losses from water erosion. The stated models have been developed and applied in various region of the world. In addition, a wide range of erosion control practices have been developed and adopted in order to contain the various problems caused by erosion. Despite the known benefit of these models their use and applications in studies carried in developing countries such as Nigeria is significantly minimal. Despite the soil and nutrient losses, 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 reduce progress on farm lands. 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 in their effort to manage soil and nutrient losses in the area. This study was conducted to estimate annual losses of soil and nutrient due to rill erosion.

II. MATERIALS AND METHODS

2.1. *Research Design*

Six different locations (comprising six sites each) that adequately represent the study area were selected based on their comparable soil properties (Origin), agricultural activities (vegetable) and land use, topography, precipitation and severity of rill erosion in the area. The selected locations or sides sufficiently, cover the rill erosion prevalent sites in Biu area Borno State. At each site 23 soil sample will be collected four filled and laboratory analysis. Soil profile will be duly and each site. Randomized complete block design (RCBD) would be used for the studies (6 x 24) = 144 soil sampling will be collected. A transect of 200m by 100m by will be selected for measurement of rill erosion features in terms of length, depth and width. Each sample will be collected when moist in a well labelled poly ethene bag. The soil sample will be air - dried sieved through a 2mm sieve and then prepared and analyze for some physical (clay content, bulk density, texture, and structure) and chemical properties (organic matter content, nitrogen, phosphorus, potassium. Magnesium, calcium and Sulphur) that relates to soil erosion. Soil infiltration rates at each location will be studied using double infiltrometer. The outer and inner rings are 50 and 25cm in diameter, and 20 and 30cm in height (Evert and Kenwar. 1992). Rain gauge will be used to collect rainfall data at each location. The above data will be used in RUSLE2, Empirical, and Nutrient Loss Models, while, the Observed Models, will use the stated length, depth and with of rill erosion features as inputs.

2.2. *The RUSLE2 Model, Version 2016*

$$a_i = r_i\, k_i\, l\, s\, c_i\, p_i \qquad (1)$$

a_i = Long - term average soil loss.

r_i = Erosivity factor.

k_i = Soil erodibility factor.

l = Slope length factor.

S = Slope steepness factor.

c_i = Cover and management factor.

p_i = Support practice factor.

2.3. *The Empirical Model*

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \ldots\ldots\ldots\ldots + \beta_{12} X_{12} \qquad (2)$$

Y = Estimate of soil loss α and β = regression parameters.

X_1 = Soil clay.

X_2 = Soil organic matter content.

X_3 = Aggregate stability.

X_4 = Infiltration rate.

X_5 = Soil bulk density.

X_6 = Plastic limits.

X_7 = Rainfall and run off factor.

X_8 = Erodibility.

X_9 = Slope length and steepness.

X_{10} = Support practice factor.

X_{11} = Vegetation.

X_{12} = Soil shear strength.

2.4. *The observed Model*

Volume of rill (m3) = 1.57 x width x depth x length - Lemma et al., (2017). (3)

Where 1.57 is χ (pie) (4)

Mass of soil loss by rills ($kgha^{-1}yr^{-1}$) = volume of rills (m^3) x bulk density (g/cm^3) x size of field. (5)

2.5. *Nutrient Loss Model*

Nutrient loss (kg) = soil loss ($kgha^{-1}yr^{-1}$) **x** % Nutrient content of soil **x** field size (ha) (6)

2.6. *Laboratory Analysis*

The particle size distribution was determined by Bouyocous hydrometer method (Day 1965, Jaiswal 2003). The textural class of the soil was determined using Marshals textural triangle as contained in Day (1965). Soil bulk density was determined on an undisturbed soil in the field using core samples (Black 1965 and Jaiswal, 2003). The total porosity of the soil was determined by Jaiswal (2003) method. Soil moisture content was determined by gravimetric soil moisture content as described by Lowery et al., (1996) method. Field capacity was determined by pressure plate method (Richard and Weaver, 1944). The Atterberg Limits composed of liquid and plastic limits, the liquid limit was determined using point cone penetrometer (BS 1377 part 2: 1990: 4.3), while the soil plastic limit was studied using one point cone penetrometer as described by Head (1992) aggregate stability was studied, using wet - serving apparatus (Eijkekamp, Netherlands) and the method of wet sieving was adapted from Kemper and Roseman (1986). Soil reaction ($_P$H) was measured in a 1: 2: 5 soil water suspension ration and also in 0.5 m KCL solution using glass electrode $_P$H meter (Black, 1965. Jaiswal 2003). The electrical conductivity of soil was measured alongside $_P$H with an EC meter using the same soil water suspension (Black 1965 Jaiswal 2003). Organic carbon was determined by Walkley and Black (1934). Potassium dichromate wet - oxidation method. Total nitrogen was studied by the Kjeldahl wet oxidation method (Bremner 1965). Available phosphorus was determined by bicarbonate extraction method (Osan and Dean 1965). Exchangeable cation was determined in the extract of 1N ammonium aceted (NH4 OAC), Black (1965). The data generated were subjected to analysis of variance (ANOVA) using statistix 10, statistical package version 10, (2013). Statistically different mean at $P < 0.05$ was separated using SE and LSD. Geometric mean error ration (GMER) and geometric standard deviation of error ration (GSDER) was used to calculate the prediction strength of both models (Empirical and RUSLE 2 predicted models.

III. RESULTS AND DISCUSSION

3.1. *Average Annual Precipitation, Rainfall and Runoff Factor and Erosivity of the Study Sites in Biu Area*

Table 1, describes the average annual precipitation, rainfall and runoff factor and erosivity distribution of the various study sites in Biu area. The rainfall data ranges from 2004 to 2025 for all the sites representing 10 years precipitation data. The average annual precipitation varied from 698.00 - 897.00 mm. The highest annual precipitation was recorded at Dam1 followed by Piku2, Piku1, Dam2, Piku2 and Kigir1 with their respective values at 897.00, 825.89, 820.00, 722.00, 699.00 and 698.00 mm. Rainfall and runoff factor varied from 447.57 - 536.43mm. The highest rainfall and runoff factor occurred at Dam2 followed by Piku1, Dam1, Piku2, Kigir1 and Kigir2 with their respective values at 536.43, 522.29, 515.43, 511.24, 495.86 and 447.67mm^3. Rainfall erosivity ranged from 355 - 486 MJmm ha^{-1} yr^{-1}. The highest erosivity or rainfall was recorded at Piku2 followed by Dam2, Dam1, Piku1, Kigir1 and Kigir2 in the order of 486, 436, 424, 366.70, 362, and 355MJmm $ha^{-1}yr^{-1}$ respectively.

Rainfall intensity varied from 25.10 - 28.70 $mmhr^{-1}$, at Piku and Kigir respectively, across sites in the study area. Higher rainfall intensities causes' high soil loss, this observation agrees with the report of Hudson, (1963) and Kowal, (1970) that rainfall intensity of about 25 $mmhr^{-1}$ was a threshold value, higher intensity than this being erosive. Rainfall erosivity is related to the intensity of rainfall. The higher the rainfall intensity the greater will be the volume of runoff water this concurs with the report of Morgan (1995), Happ (2014) and Mbarjiorgu *et al.,* (2015) that erosivity is closely related to the intensity of rainfall. The higher the rainfall intensity the greater will be the volume of runoff water per unit time and the higher the velocity of runoff. Dam1 site with high annual precipitation had high risk of erosion than Piku2, Piku1, Dam2, Kigir1 and Kigir1 sites. Precipitation, rainfall and runoff factor and erosivity are significant at ($p< 0.05$). The average annual erosivity, rainfall and runoff factor 'R' is an index of erosivity at a location (the study area). Erosivity reflects the effect of both rainfall amount and rainfall intensity on soil erosion. The 'R' values in the study area ranged from moderate to high. This showed that, most of the rills and interill erosion were caused by moderate to high rainfall conditions within the study sites that was why the 10 yr – 24 hr precipitation was chosen for calculation of the runoff (Morgan, 1986: USDA - ARS, 2008). 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 Blanco and Lal, (2008); Biswass and Mukherjee, (2008) and Happ, (2014). The intensity of soil erosion was high in the study sites because of the nature of slope. The runoff transported the sediments downhill to valleys and streams this observation concurs with the report of Olderman, (1998): WHO, (2000) and Pimental, (2013) that the impact of soil erosion was intensified on all slopping lands, where with each degree of slope of the surface, soil was carried away as the water moves downhill into valleys and streams. Sites with high rainfall and runoff factors (Dam2, Piku1 and Dam1) had high precipitation, volume, intensity, duration and pattern of rainfall than sites with low rainfall and runoff factors (Piku2, Kigir1 and Kigir2) (Table 1). Sites with low slope steepness or degree had low erosivity values. This observation agrees with the report of Abdulrahaman *et al.,* (2015) that rainfall and runoff factor is greatly affected by the volume, intensity duration and pattern of rainfall, whether for single storm or a series of storms and by the amount of and rate of the resulting runoff. Areas with low slope degree have low erosivity values which imply that flat areas would increase the water ponding on the surface, thus protecting soil particles from being eroded by raindrops.

Table 1. Average annual precipitation, rainfall and runoff factor, and erosivity at various sites in Biu Town.

Study Site	**Annual Precipitation (mm)**	**Rainfall and Runoff factor (R) (mm)**	**Erosivity (MJ mmha $hr^{-1}yr^{-1}$)**
Piku 1	820.00A	522.29C	366.70D
447.57F	355.00F	511.29D	486.00A
0.1161	0.0387	515.86B	424.00C

Dam 2	722.00B	536.43A	436.00B
Kigir 1	698.50B	495.86E	362.00E
Kigir 2	699.00B		
SE$_{0.05}$	23.121		

Source: 2025. SE = Standard Error. Mean followed by the same letter (s) in a column are not at $p < 0.05$ significantly different.

3.2. *Annual Soil Loss Estimated by Measured, Empirical, and RUSLE2 Models*

Annual soil loss by rill erosion estimated by measured, empirical and RUSLE 2, models in the study sites are presented in Table 2. The result showed that in 2020, the predicted annual soil loss varied from Kigir2 (165.67 kgha^{-1}yr^{-1}) to Piku2 (388.86 kgha^{-1}yr^{-1}). The soil loss estimated by empirical model ranged from 395.72 kgha^{-1}yr^{-1} at Kigir2 to 629.53 kgha^{-1}yr^{-1} at Piku1. The RUSLE 2 predicted soil loss was significantly ($P<0.05$). Soil loss estimated by RUSLE2, varied from 150.00 kgha^{-1}yr^{-1} at Kigir2 to 495.00 kgha^{-1}yr^{-1} at Piku1. The annual soil losses across sites in the study area was influenced by the intensity of rainfall recorded (Table 1), soil erodibility, slope length and steepness, vegetation and protection management factor, this observation concurs with the report of Moller and Sisheber (2017) that soil erosion is influenced by soil erodibility, rainfall intensity, slope length and steepness, vegetation (poor land cover), and protection management factor (improper land management). The differences in terms of the model's estimation could have been due to slope length and steepness, watershed size, surface obstruction, and relatively higher rates of basic cations saturating its soils. This observation agrees with the report of Pimental and Burgess (2013). Abdul Rahaman et al., (2015) reported similar relevance of such watershed characteristics, and high basic cations in abating soil loss. That the rate of soil erosion ranged from very severe (50 - 200 m^{3}ha^{-1}yr^{-1}) to catastrophic erosion (> 200 m^{3}ha^{-1}yr^{-1}) across sites, estimated by empirical and RUSLE2 models (Abdulrahaman et al., 2015).

Table 2. Annual soil loss (Kgha^{-1}yr^{-1}) estimated by measured, empirical and RUSLE2 models.

Study site	**Measured**	**Empirical**	**RUSLE**
Piku 1	340.05B	629.53A	495.00A
Piku 2	388.86A	500.90BC	320.00B
Dam 1	178.12D	497.92BC	290.00C
Dam 2	200.87C	526.98B	249.00D
Kigir 1	174.74E	430.67C	236.00E
Kigir 2	165.67F	395.72D	150.00F
SE$_{0.05}$	0.108	24.31	0.104

Source: 2025. SE = Standard error. Mean followed by the same letter (s) in a column are not significantly different at $p < 0.05$.

3.3. *Prediction Strength of Empirical and RUSLE2 Models in the Study Area*

The soil loss in terms of empirical and RUSLE 2 models in 2025, is presented in Table 3. Empirical model soil loss ranged from 395.72 - 530.67 kgha^{-1}yr^{-1}, and RUSLE2 soil loss varied from 150.00 - 395.00 kgha^{-1}yr^{-1}, respectively. The Geometric mean error ration for empirical model was 0.824, and geometric standard deviation of error ratio for empirical model was 4.00, respectively. The geometric mean error ratio for RUSLE2 model was 0.41 and the geometric standard deviation of error ratio for RUSLE 2 models was 4.00, respectively. GMER < 1 indicates that predicted values are generally under estimated. GMER > 1, points to general over prediction. GSDER = 1, correspond to perfect matching and it grows with deviation from measured (or estimated) data. Therefore, the best model will be the model that will give a GMER close to 1, and a smaller GSDER (Walter, 1985). Empirical model surpassed because of GMER closed to 1 and smaller GSDER in the study area in both stated years. Also, the empirically estimated model had high prediction strength than RUSLE2 predicted model. Unlike RUSLE2 predicted, the empirically estimated model has no any depth of soil restriction, and it was fashioned to behave like RUSLE2 predicted model in the study area. RUSLE2 predicted model is restricted to 30 cm depth of soil application and was designed in the United States of America (USDA - NCRS, 2008; USDA - ARS, 2008).

Table 3. Predicting strength (kgha^{-1}yr^{-1}) of Empirical and RUSLE2 Models using GMER and GSDER.

Study Site	**Empirical Model**	**RUSLE**
Piku 1	530.67	395.00
Piku 2	500.90	320.00
Dam 1	497.92	290.00
Dam 2	526.98	249.00
Kigir 1	629.53	236.00
Kigir 2	395.72	150.00
GMER	0.824	0.461
GSDER	4.00	7.21

Source: 2025. GMER = Geometric mean error ratio, GSDER = Geometric standard deviation of error ratio.

3.4. *Annual Validation of Soil Loss using Measured and RUSLE2 Models in the Study Area*

Fig 1 (a - b), show the performance of RUSLE2 and empirical models in predicting soil loss in the entire study area in 2025. The model recorded the r^2 values of 0.8553 and 0.5450 for both first and second estimation. The RUSLE2 model prediction accuracy in Biu area, in terms of soil loss was 85.53 and 54.50%. This observation concurs with the report of Thomaz, (2013) about the range of 44.9 - 92%. The model's high prediction ability across sites was because it is land use independent and applies to all conditions where rill erosion occurs when natural soil is exposed to the erosive forces of impacting raindrops and water drops falling from vegetation and runoff produced by Huttonian overland flow. This observation concurs with the report of Foster et al., (1997) and Lemma et al. (2017), that the RUSLE2 (2016) was land use independent and applies to all conditions where rill erosion occurs when natural soil was exposed to the erosive forces of impacting raindrops and water drops falling from vegetation and run off produced by Huttonian overland flow. The model had predicted the soil loss at all the sites under different climate and land use conditions consistently. The model predicted a linear increase in rill erosion with increasing rainfall intensity, which reflect the influence of both rainfall depth and rainfall intensity (Table 1). This observation concurs with the reports of USDA - ARS, (2008) and Dabney et al., (2012) that the model application under different climate and land use conditions had been consistent, and predicted a linear increase in rill erosion with increasing rainfall intensity, which reflect the influence of both rainfall depth and rainfall intensity.

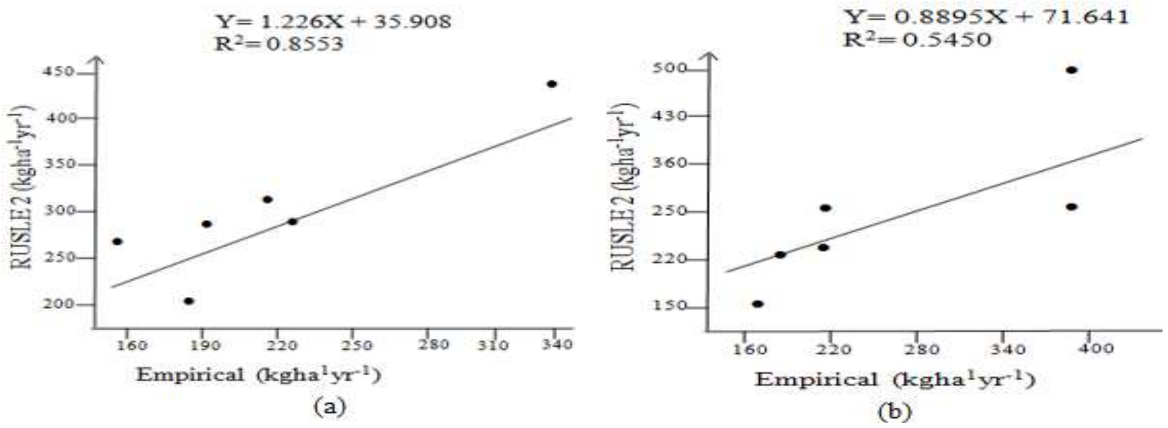

Fig. 1. Annual validation of soil loss using measured and RUSLE2, estimates in the study area 2025.

3.4. *Nutrient loss in Biu Town*

The soil organic matter loss ranged from 1.85 to 3.88 kgha^{-1}yr^{-1}. The soil organic matter loss across sites was higher ($p < 0.05$) at Piku1 followed by Piku2, Kigir1, Dam2, Kigir2 and Dam1 with their respective values at 3.88, 2.81, 2.71, 2.37, 2.27 and 1.85kgha^{-1}yr^{-1}. The organic matter loss occurred through the sediment as earlier reported by Lemma et al., 2017. The soil nitrogen loss across sites varied from 1.04 to 2.26kgha^{-1}yr^{-1}. The loss of nitrogen was higher ($p < 0.05$) at Piku1 followed by Piku2, Kigir1, Dam2, Kigir2 and Dam1 with their values at 2.26, 1.53, 1.47, 1.30, 1.16 and 1.04kgha^{-1}yr^{-1}, respectively. Soil nitrogen across sites was loss through the sediment rather than runoff as earlier stated by Zhang 2016. Soil phosphorus loss ranged from 1.07 to 1.99kgha^{-1}yr^{-1}. Soil P loss was higher ($p < 0.05$) at Piku1 followed by Piku2, Kigir1, Dam2, Dam1 and Kigir2 with their respective values at 1.99, 1.38, 1.24, 1.16, 1.11 and 1.07kgha^{-1}yr^{-1}. The soil P was adsorbed to the colloid and the transport was most intense in clay fraction resulting in greater losses with sediment runoff as earlier stated by Vasconcellos et al., (2021). Soil K loss ranged from 1.12 to 2.78kgha^{-1}yr^{-1}. Soil K loss was higher ($p < 0.05$) at Piku1 followed by Piku2, Kigir1, Dam2, Kigir2 and Dam1 with their respective values at 2.78, 1.88, 1.77, 1.63, 1.49 and 1.12kgha^{-1}yr^{-1}. The loss of soil K was closely related to the amount of sediment loss from soil erosion as earlier reported by Allincal et al., 2011 and Happ 2014. Soil Ca loss ranged from 2.10 to 3.59kgha^{-1}yr^{-1}. Soil Ca loss was higher ($p < 0.05$) at Piku1 followed by Piku2, Kigir1, Dam2, Kigir2 and Dam1 with their values at 2.40, 1.74, 1.65, 1.56, 1.38 and 1.19 kgha^{-1}yr^{-1}, respectively. Soil Mg loss ranged from 1.13 to 1.90 kgha^{-1}yr^{-1}. Soil Mg loss was higher ($p < 0.05$) at Piku2 followed by Piku1, Dam2, Kigir2, Kigir1 and Dam1 with their values at 1.90, 1.52, 1.51, 1.43, 1.25 and 1.13 kgha^{-1}yr^{-1}, respectively. Soil Ca and Mg losses across sites occurred through the colloid facilitating their transport into the sediment as earlier stated by Mikelson 2010; Vasconcellos et al., (2012). Soil Sulphur (S) loss ranged from 1.20 to 1.94 kgha^{-1}yr^{-1}, across sites. Soil S loss was higher ($p < 0.05$) at Piku2 followed by Kigir1, Kigir2, and Dam2, Dam1 and Piku2 with their respective values at 1.94, 1.56, 1.35, 1.35, 1.20 and 1.04 kgha^{-1}yr^{-1}. The loss of soil S across sites was closely related to the amount of sediment loss from soil erosion as earlier reported by Allincal et al., 2011 and Happ 2014.

Table 3. Soil nutrients loss at various sites in Biu Town.

Site	O.M	N	P	K	Ca	Mg	S
				Kgha^{-1}yr^{-1}			
Piku 1	3.88A	2.26A	1.99A	2.78A	2.42A	1.52B	1.04E

Site	O.M	N	P	K	Ca	Mg	S
Piku 2	2.81B	1.53B	1.38B	1.88B	1.74B	1.92A	1.94A
Dam 1	1.85E	1.04F	1.11E	1.12F	1.19F	1.13F	1.22D
Dam 2	2.37D	1.30D	1.16D	1.63D	1.56D	1.50C	1.35C
Kigir 1	2.71C	1.47C	1.25C	1.77C	1.65C	1.25E	1.56B
Kigir 2	2.27D	1.16E	1.07F	1.49E	1.38E	1.43D	1.35C
SE $_{0.05}$	0.036	9.159	5.528	7.949	9.027	8.650	8.650

Source: 2025. KEY: SE = standard error, O.M = organic matter, N = Nitrogen, P = Phosphorus, K = Potassium, Ca = Calcium, Mg = Magnesium, S = Sulphur. Mean followed by the same letter (s) in column are not significantly different at $p < 0.05$.

IV. CONCLUSION

The severity of rill erosion was quantified using empirical and RUSLE2 models prediction techniques under same condition of Biu environment. RUSLE2 estimates rates of rill and interill soil erosion caused by rainfall and its associated overland flow. Soil nutrients (N, P, K, Ca, Mg and S) were also estimated at all the sites. The pattern, rate and estimates of soil and nutrients losses were confined to rainfall amount as the season progressed to a peak in the month of July and therefore decline with cessation of rainfall in October in the study area. Soil and nutrients loss was significantly ($p < 0.05$) higher at Piku1 and Piku2 followed by Dam1 and Dam2, and then Kigir1 and 2 in this study. RUSLE2 model gave high prediction accuracies of soil loss, while the empirical model had moderate accuracies in terms of soil loss prediction in the study sites. However, both models showed low to high prediction strength at locational bases. On aggregate basis empirical model surpassed with greater strength of prediction accuracy than RUSLE2 model. But both models showed severe soil and nutrient losses in the Biu area.

4.1. *Recommendations*

i. *Terraces*

Terraces are mechanical structures such as an earthen ridge or stone wall which reduces the slope steepness and divides the slope into short gentle sloping sections. Terraces reduces the runoff velocity and soil loss, increases the soil moisture content through improve infiltration, reduce evaporation and can be created to divert runoff to a prepared or safe area for minimizing the effect of soil erosion to a tolerable level.

ii. *Contour Bunds*

As progressive terraces, contour bunds are suited to flat areas of slope less than 16 %. Contour bunds can reduce the soil erosion and increase the soil water holding capacity in the intervention area.

iii. *Check Dam*

Check dams are structures constructed across a channel or a river to lesson water velocity and to catch sediments.

iv. *Anti - Erosive Ditches*

An anti-erosive channel is a drainage channel constructed to prevent runoff water from upper hill to enter a c-

-ropped land. In this channel, water may infiltrate or may be diverted.

v. *Grassed Waterways*

Grassed waterways are more important in filtering by retaining runoff sediments, pollutants and other particulate matter within storm water and their performance will depend on soil permeability within the area.

vi. *Hill Side Water Ponds*

Rain water harvesting is a system of collecting water through different technologies such as storage of rain water on surface reservoirs and ground water recharge for future use. The use of ponds for retaining water reduces soil erosion.

vii. *Retaining Walls Made of Gabions for Slope Stabilization*

Retaining walls are structures made of masonry, stone, brick, concrete or combination of these. They are used as erosion control structures. Comparatively to other retaining walls, the main advantage of gabions retaining walls is to reduce the runoff velocity or to increase the stability of sloping surface area with seepage problems.

REFERENCES

[1] Abdulrahman, S Auchamy, S. Jegenkumal R. and Abdelaziz S. (2015) Estimation of Annual soil loss based on RUSLE Model in kalar water shed basic, Tamil Nadu, India. ISPRS Annals of the photogating Remote Sensing and special information science volume 11 to 2/ W2. Joint international geoinformation conference 2015: 28 - 30 October 2015 Kuala Lumper Malaysia.

[2] Ahmed N.S Mustapha F.B Yusuf S Didymus, G.A (2020) it is systemic review of soil erosion control practices on agricultural land in Asia Int, J soil water conservation Res 8 105-115.

[3] Allincal, C. Jitaremun, G Barcur, D and Alliance D 2011, water run of and soil erosion register. In different crops on 16% shape lands Cerveteri Adormisc in Moldova, Vol. XLIN. No. 3 (147) PP 20.

[4] Angasi A. (2014) effect of Glenzing intensity and bush encroachment on herbaceous species and rangeland condition in southern Ethiopia. Land Degradation Dev. 25.

[5] Baptista, I Rizema C, and Giessen, V, (2015) effect of integrate water nutrition management structure on soil erosion medicated nutrient loss and crop producibility caboverder Drglengs Phis one 10 (7) EO, 1342244/Journal phone 01342444.

[6] Biswass, T.D., and Mukherjee, S.K., (2008). Test Book of Soil Science, 2nd Edition, published by the Tata McGraw - Hill Publishing Company Limited, 7. West Patel Nagar, New Delhi 110 and Printed at Puship Print Services Jujpaw, Delhi. Pp. 340.

[7] Blanco H, Ratan L, (2008) principles of soil conversation and management springer science business media, the Ohio State University collection O.H. USA Kansan State University USA.

[8] Dabney, S.M, Yodder D. C. and Vieira D. A.M (2021) the application of the revised universal soil loss equation, version 2 to evaluate the importance of alternative climate change scenarios on run off and sediment yield Journal of soil and water conservation, vol. 67, No. 5.

[9] Defershal, M. B., Qurasha, S. and Mellesse, A., (2011). The Effects of Slope Steepness and antecedent moisture content on inter - rill erosion, run off and sediment size distribution in highlands of Ethiopia. Hydrol, Earth system sci. 15, 2367 - 2375.

[10] Everts, C.Y. and Kenwar, R.S. (1992). Interpreting Tension Infiltration Data for Quantifying Soil Micropores: Some Practical Considerations. Trans ASAE: 36: 423-428.

[11] Gelder, B., Sklener, T., James, D., Hertzmann, D., Cruse, R., Gesch, K., Laflen, J. (2017). The Dialy erosion project - daily estimates of water runoff, soil detachment. Earth Surf. Process Landf 43, 1105 - 1117.

[12] Happ, M., (2014), Impacts of land cover change and high rainfall on soil erosion among three farms in Cero Punta, chiriqui, Panama. Independent study project (ISP) collection paper 2002. 43: 1115-1117.

[13] Huang, Y. Chen, X., Luo, B., Ding, L. and Gong, C., (2015). An Experimental Study of Rill Erosion Sediment Delivery in purple Soil using the Value replacement method peer Journal 3e 1220: DDI. 10.771.

[14] Hudson, N.W., (1963). Raindrop Size Distributions in High Intensity Storms: Rhod. J. Agric. Res. 1: 6-11.

[15] Jaiswal P. (2003) Soil Plant and water analysis Kalyni publication Ludlina Delhi Norda Hydrcvate India.

[16] Lemme, B. Kebede, F, Mextfam, S. Abraha, Z. and Musgrave, I (2017) Quantifying annual soil loss by Rill erosion in contention usual Semi-Arid farmlands. North Ethiopia environment Earth science 76: 190.

[17] Lowry, B. Aoshed M. A. Lal and Hickey, W.J. (1996) soil water parameter and soil quality in J.W Doran and A.J James (EDS) methods for assisting soil quality. Soil science society of American special publication 49555A Madison WI 143-151

[18] Mikleson, R., (2010). Soil and Fertilizer Magnesium, North America, Better Crops / vol. 94, No 2.

[19] Molla, T. S., and Sesherber, B. (2007. Estimating soil erosion risk and evaluating erosion control measures for soil conservation planning at Koga watershed in the high of Ethiopia. Solid Earth, 8: 13 – 25.

[20] Morgan, R.P.C, Morgan, D.D.V. and Finney, H.J. (1984). A Predictive Model for the Assessment of Erosion Risk, J. Agricultural Engineering Research 30: 245 - 253.

[21] Morgan, R.P.C., (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.

[22] Olderman, I.R., (1998). Soil Degradation; A Threat to food Security, Report 98/01; International Soil Reference and Information Centre. Wageningen, The Netherlands Pimental, D., and Burgess, M. (2013). Soil Erosion Threatens Food Production. Agriculture, 3, 443-446, doi: 10. 3390/agriculture, 3030443. pp. 443-450.

[23] Shafagh, R, Braimi, H., Darajani, A., Sheikh Gurbani, J. and Gurbani, M., (2015). Economic cost of soil nutrient loss from summer rangelands of Nour rad watershed in North Iran.ECOPESIA. 3(2), 945-958.

[24] Renard, K.G, and Smith, D. D. (1997). Predicting Soil Loss Erosion by Running Water. A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE), Washington D. C. USA (United States Department of Agriculture).

[25] Rastagar, S.H. (2015). Estimating and comparing the economic value of forage production and soil conservation range vegetation case study of Nour - rad watershed Basin Mazara drum province Ph.D. Theses. Georgia University of Agric. Science and Natural Resources 158.

[26] Vasconcellos da silva, G.R., Menezes de Souza, Z., Martins Filho, M.V., Barbosa, R.S., and Soares de Sauza, g., (2012). Soil, Water and Nutrients Losses by Interill Erosion, from Green Cane Cultivation, R. Beans ci. Salo, 36: 963-370.

[27] Vipul. S, Tiwan. K.N and Magrijalishee S, (2010) priotization of micro watershed on the basic of water erosion Harland Using remote Sensing and Geometric information system. International journal of water resource and Environmental Engineering Vol. 2 (30). Pp 130-136.

[28] Ypsilantis. B, (2011) up land soil erosion monitory assessment: an overview, Bureau of Land management environmental quality and protection, washmen DC tactical note: 438 pp6.

[29] Wishmier, W. H. and Smith, D.D. (1958). Rainfall Energy and its Relationship to Soil Loss Transaction of the American Geophysical Union 39: 285-291.

[30] World Health Organization (WHO) (2000). Nutrition for Health and Development; A Global Agenda for combating malnutrition progress Report; Sustainable Development and Healthy Environment (SDE); Rome, Italy.

[31] Zhang, G. (2016). Characteristics of Runoff, Nutrient Loss and Particle Size Distribution of Eroded Sediment under Varied Rainfall Intensities, 4th International Conference on Machinery, Materials and Computing Technology (ICMMCT), (2010) Published by Atlantic Press. Pp. 591.

AUTHOR'S PROFILE

Ibrahim Madu, College of Education Waka-Biu, School of Vocational Education, Department of Agriculture Education, P.M.B. 1502, Waka-Biu, Borno State, Nigeria.