



PREDICTION OF SOIL AND NUTRIENT LOSS RATES FROM RILL EROSION IN BIU AREA, BORNO STATE, NIGERIA

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ABSTRACT

The study was conducted on monthly and annual bases between March and December during 2020 at Biu area of Borno state consisting of six different sites (Piku, Kigir, Dam, Mirnga, Mandaragrau and Gunda) to estimate annual losses of soil and nutrient (N, P, K, Ca, Mg and S) due to rill erosion and to validate RUSLE2 model for prediction accuracies. The annual precipitation varied from 699.00 – 896.00mm. and the rainfall erosivity ranged from 351.00 – 485.00 MJmmha⁻¹hr⁻¹yr⁻¹, respectively across the sites. Soil erodibility (0.70 – 0.80) slope length (435.00 – 785.00m), and slope steepness (6 – 9%) cover management factor (0.12 – 0.23) and protection management (0.12) were used as predictor variables in Revised Universal Soil Loss Equation Version 2 (RUSLE2) 2016, across the sites. Six hectares of overland flow sites consisting of rills were selected randomly at each site for the study. About 168 soil samples were collected from six sites. The RUSLE2 model annual estimation of soil loss was 260.00 – 447.00 and 150.00 – 495.00 kg ha⁻¹yr⁻¹, respectively. Annual validation RUSLE2 revealed the r² value of 0.8553. High soil and nutrient (O.M, N, P, K, Ca, Mg, and S) loss were recorded at Piku site with their respective values of 447.00, 3.82, 2.22, 1.95, 2.72, 2.35, 1.49 and 1.02 kg ha⁻¹yr⁻¹. Recommending the management of terraces, mulching, cover crops and vegetation, no – tillage method, buffer zones, contour bonds, check dams, grassed water ways and hillside water ponds to reduce the length of the slope and consequently the soil and nutrient loss.

Keywords: Erosion, Nutrient, Loss, Precipitation, Density, Erodibility

INTRODUCTION

Soil erosion is the detachment, movement and removal of soil from the land surface by precipitation leaving the landscape as run-off. Degradation of agricultural land by soil erosion is a worldwide phenomenon leading to loss of nutrients rich surface soil, increase run-off from more impermeable subsoil and decreased water availability to plant (Vipul *et al.*, 2010, Gelder *et al.*, 2017, Orgiazzi and Paragos 2018, Ahmed *et al.*, 2020 and Stefanidis *et al.*, 2022). Water erosion causes a series of on-site as well as off-site damages and problems on natural ecosystem. These damages include soil and nutrients loss and finally loss of productivity. Considering that mountain soils are 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). Each year, about 10 Mha of crop land are lost due to soil erosion, thus reducing the cropland available for world food production, overall, soil is being lost from agricultural areas 10 to 40 times faster than the rate of soil formation impairing humanities food security (Pimental and Bager, 2013).

The typical nutrients loss after 10 mm top soil is eroded, is equated to total nitrogen, phosphors, potassium and calcium to the order of 243.6, 90.0, 200.8, 650, and 1050 kg ha⁻¹yr⁻¹, respectively (Thompson and Basher 1999). In slopping land, soil and nutrients (NPK) losses were in the order 4.451 kg ha⁻¹ yr⁻¹ and 10.71-11.26, 0.56-0.64, 0.98-1.11 kg ha⁻¹yr⁻¹, respectively (Allincal *et al.*, 2011). In USA, Europe and India, soil loss recorded in the order of 8.84 t ha⁻¹yr⁻¹, 150 and 130 M t ha⁻¹yr⁻¹ respectively. In Iran and Uganda, soil and nutrients losses were estimated to be 27.44 t ha⁻¹yr⁻¹, 114.20 kg ha⁻¹yr⁻¹, 114.8 t ha⁻¹yr⁻¹ respectively (Izaraide *et al.* 2007; Montamarella, 2008; Semalulu *et al.*, 2014; Abdulrahman *et al.*, 2015; and Rastgar *et al.*, 2015). Nigeria with a land area of 910,771 km²



of which 37.33 % is currently put under arable 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 pronounced in the southern parts compared to the northern parts of Nigeria, as a result of regional precipitation (amount and intensity and soil types (Lal, 1995 World Bank Report 2010, CIA, 2012). However, the vast bare lands and intensified agricultural activities in northern Nigeria predisposed the soil to greatest rates of water erosion on disturbed upland area which made the rills to be active in the northern guinea Savannah (Amaza, 2007).

Among the forms of water erosion (sheet, inter rill, rill gully, ephemeral gully and stream bank), rill erosion, remains the main cause for concern, since it contributes significantly to water and soil loss (high sediments concentration), thus removing organic matter and Productivity of soils decline through the consequences of soil loss and erosion, especially top soil, because of loss nutrients, physical deterioration that is change of land form and decrease of soil thickness which reinforced unexpected change in land use. For this reason, estimation of soil loss and or is crucial to implement preventive measures. Despite the soil and nutrients 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 soil and nutrients loss on farmlands. The objectives of the study are to:

- estimate soil and nutrient loss in the study area, and to measure soil and climate parameters that influence rill erosion in the study area.

MATERIALS AND METHODS

The Study Area

The study was conducted in Biu Local Government Area, Borno State, North eastern Nigeria, in 2020. Six sites; Kigir ($10^{\circ} 35' N$, $12^{\circ} 12' E$), Dam ($10^{\circ} 37' N$, $12^{\circ} 9' E$), Piku ($10^{\circ} 37' N$, $12^{\circ} 11' E$), Mirnga ($10^{\circ} 43' 16' N$, $12^{\circ} 8' 54' E$), Mandaragrau ($10^{\circ} 35' 52' N$, $12^{\circ} 12' 30' E$), Gunda ($10^{\circ} 55' N$, $11^{\circ} 55' E$), were used for the study and soil sampling was conducted at each of the sites. In each site, 6 hectares of land were selected at random, (Shipitalo and Edward, 1998). At each site, four (4) land forms (crest, shoulder, back slope and fore slope), were identified and on each land form, one (1) soil sample at 30 cm depth, was collected, making the total of 24 samples, per each site. Since there are six locations (sites) (6×24) samples = 144 samples were collected for laboratory analysis. Also, at each site a Transect of 200 m by 100 m was selected. Each soil sample was collected when moist in a well labelled Polyethylene bag. The soil samples were air – dried sieved through a 2 mm sieve then prepared and analyzed for some physical and chemical parameters that relates to soil erosion. All the soil samples were collected at the end of the growing season.

The organic carbon content of the soil sample was determined using Walkley and Black (1934) potassium dichromate wet – oxidation method. The value of organic matter was obtained by multiplying the organic carbon content of the soil by a factor of 1.724 (Walkley and Black, 1965). Total nitrogen content of the soil was determined by the Kjeldahl's wet digestion method (Bremnar, 1965). Available phosphorus content of the soil sample was determined by bicarbonate extraction method (Olsen and Dean 1965) for near neutral and slightly alkaline soils while for acidic soils, determination of the available phosphorous was done by Bray No 1 method (Black, 1965). The exchangeable cations in the soil samples were determined in the extract of 1N ammonium acetate (NH_4OAC) (Black 1965). The exchangeable cation and magnesium cation of the soil were determined titrimetrically while the exchangeable potassium and sodium was determined by flame photometer. Sulphur was determined by calorimetric method using methyl blue (Tabatabaei, 1982).

The rainfall was collected using a rain gauge devise for all rainfall events during the study period. The K- factor represents the combined effect of soil texture, organic matter, permeability, and structure on average long-term erosion. The slope length was measured by GPS tool and slope steepness was calibrated by Theodolite. Cover management factor that is the C value was measured by semi detail survey of the crops grown on the field. Support practice factor was measured by semi detail survey of the terraces on the slope. Support practice factor (P) in RUSLE2 is defined as the ratio between soil loss with a specific support practice and the corresponding loss with upslope and down slope tillage.



Nutrient Content Determination

Soil nutrient content was determined by Harvey and Baker (2002) method;

Soil nutrient content = Soil nutrient (kg or %) x Soil bulk density x Depth of soil x Area of soil

Soil Nutrient Loss Determination

Surface runoff and soil loss were calculated from the six stated sites in the study area. Soil loss, nitrogen, phosphorus, potassium, magnesium, calcium and sulphur in the sediments were analysed in the laboratory. Sediment yield volumes were determined during 2020 runoff seasons, in the study area. The soil samples were air dried pass through a 2 mm sieve. The nutrient loss was calculated by Lemma *et al.*, (2017) model:

Nutrient loss (Kg) = Soil loss (Kg ha⁻¹ yr⁻¹) x % Nutrient content of soil x Field size (ha).

Measured Model Estimation (Observed)

Volume of rill (M³) = 1.57 x width x depth x length - Lemma *et al.*, (2017).

Where 1.57 is $\pi/2$

Mass of soil loss was estimated using the below equation

Mass of Soil Loss by rills (kg ha⁻¹ yr⁻¹) = volume of rills (M³) x Bulk density (t/m³) / Field size (ha)

RUSLE2, Predicted

$a_i = r_i k_i l S c_i p_i$ - USDA – ARS, (2016)

Where:

a_i = long – term average soil loss for ith day

r_i = erosivity factor

k_i = soil erodibility factor

l = slope length factor

S = slope steepness factor

c_i = cover and management factor

The Empirical Model

$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \dots + \beta_{12} X_{12}$

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

RESULTS AND DISCUSSION

Average Annual Precipitation, Rainfall and Runoff Factor and Erosivity Density

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 – 2011 and 2020 - 2021 for all the sites representing 10years precipitation data. The annual precipitation ranged from (604.80 - 1,045.40 mm) at Kigir and Piku (600.67 – 1001.97 mm), Dam (529.72 – 1050.99mm), Mirnga (567.56 – 1129.30 mm), Mandaragrau (628.4 – 1108.45mm) and Gunda (534.89 – 1147.80 mm). The average annual precipitation varied from 699.00 – 896.00 mm. The highest annual precipitation was recorded at Dam followed by Kigir, Piku, Mirnga, Gunda and Mandaragrau sites with their respective values at 896.00, 825.89, 810.00, 702.00, 699.00 and 697.00 mm. Higher rainfall

intensities across sites in the study area 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.

Table 1: Average Annual Precipitation, Rainfall and Runoff Factor, and Erosivity at Various Sites in Biu Area

Study site	Annual PPT. (mm)	Rainfall and Runoff Factor (mm)	Erosivity (MJmmha ⁻¹ hr ⁻¹ yr ⁻¹)
Piku	810.00A	512.29C	365.7D
Kigir	825.89A	510.29D	485.00A
Dam	896.00A	514.86B	414.00C
Mirnga	702.00B	535.43A	435.00B
Mand.	697.50B	494.86E	361.00E
Gunda	699.00B	446.57F	351.00F
SE 0.05	23.121	0.1161	0.0387

Source; 2020

SE = Standard error, Mand. = Mandaragrau site

Means followed by the same letter (s) in a column are not significantly different at $p < 0.05$

Soil Erodibility

The soil erodibility factor (K) of the various sites (Table 2), revealed the resistance of soil to both detachment and transport. Soil erodibility factor (K) ranges from 0.70 – 0.80 across sites. The highest soil erodibility factor was recorded at Dam, Mirnga, Mandaragrau and Gunda sites at the range of 0.82 and the lowest value was recorded at Piku and Kigir with their respective value at 0.70. Table 7 reveals soil erodibility factor (K). Dam, Mirnga, Mandaragrau and Gunda sites had high soil erodibility than Piku and Mirnga sites. Erodibility defines the resistance of the soil to both detachment and transport.

The stated sites with high erodibility had low level of organic matter, low soil infiltration rates, low porosity and high run off depicting high soil erosion risk, and the sites with low erodibility showed low soil erosion risk. This concurs with the report of Peng *et al.*, 2008; Gimenez – Moreira *et al.*, 2010; Leh *et al.*, (2013), that soil erodibility depends on soil and geological characteristics, such as parent materials, texture, structure, organic matter content, porosity, catena and many more. Mirnga site had high silt content than Gunda, Kigir, Dam and Piku sites (Figure 3). Soil with high silt content has low resistance to detachment and transport than soil with lesser silt content. This observation agrees with that of Mhangara *et al.*, (2012) that generally, soil become of low erodibility if the silt content is low, regardless of corresponding high content in sand and clay fraction.

Topography

Table 2 depicts slope length and steepness of the study sites. Kigir recorded the highest slope length of 785.00 m followed by Piku, Mirnga, Dam, Gunda and Mandaragrau sites with their respective values of 713.00, 665.00, 643.00, 508.00 and 435.00 m. Also, Piku recorded the highest steepness followed by Kigir, Mirnga, Dam, Mandaragrau, and Gunda with their respective values at 9.00, 8.00, 7.00 and 6.00. Slope length ranged from moderate to high, while percentage of slope was ranked high in terms of soil loss across sites. Kigir site with high slope length and percentage has high risk of soil erosion than Piku, Mirnga, Dam, Gunda and Mandaragrau sites with shorter length and considerable percentages of slope steepness as a result of volume and velocity of runoff in the sites. Soil erosion occurred in all the sites, because of the percentages of slope steepness were above 5 %. This observation concurs with that of Stefanidis *et al.*, (2022), that percentage slope steepness less than 5 % erosion hazard is negligible.

Cover Management Factor

The cover management factor (C – Value) of the study sites (Table 2) in 2020, ranged from 0.12 - 0.23. The highest C – value was recorded at Mirnga followed by Piku and Kigir and then Mandaragrau and Dam sites and their values which were recorded at 0.23, 0.14, 0.12, 0.12, and 0.12



respectively. The vegetation varies from grain corn and corn soybean rotation with ridge tillage at all the sites. The vegetation of the various sites varied from guinea corn, bean, and soybean, grain corn with ridge tillage and chisel plow. The C – value is dimensionless with values between 0 and 1 (Molla and Sisheber, 2017).

Protection Management Factor

Table 2 depicts protection and management factor (P – Value) in terms of land used. The study sites ranged within slope percentage of 5 – 10 %, respectively. Piku sites had the highest P – value followed by Kigir, Mirnga, Dam, and Mandaragrau. Protection and management factor (P – value), and topography of the study sites showed that Piku (9%) had high slope percentage followed by Kigir (8%) Mirnga (7%) site, Dam, Mandaragrau and Mirnga sites recorded the same value of 6%. Also, the P – value of all the sites was 0.12. The P – value reduce the amount and rate of the water runoff, and then reduced the amount of soil erosion. This observation concurs with that of Wishmeir and Smith (1978) and Renard *et al.*, (1997) that the P factor reflects the practice that will reduce the amount and rate of the water runoff and thus reduce the amount of soil erosion.

Table 2: Soil Erodibility Factor, Slope Length and Steepness, C and P Values of the Various Study Sites in Biu Area

Study sites	Soil erodibility (k)	Slope len.	Slope %	C – Value	P - Value
Piku	0.70B	713.00B	9.00A	0.14C	0.12
Kigir	0.70B	785.00A	8.00B	0.14C	0.12
Dam	0.82A	643.00D	6.00D	0.12D	0.12
Mirnga	0.82A	665.00C	7.00C	0.23A	0.12
Mandaragrau	0.82A	435.00F	6.00D	0.12D	0.12
Gunda	0.82A	508.00E	6.00D	0.12D	0.12
SE _{0.05}	4.869	2.556	0.064	3.776	

Source: 2020

Key : SE = Standard error, Mand. = Mandaragrau site, C – values = cover and management factor, P – value = protection and management factor, Slope len. = slope length, Slope % = slope steepness.

Means followed by the same letter (s) in a column are not significantly different at $p < 0.05$

Soil Loss Rates in Biu Area

Annual soil loss by Empirical and RUSLE 2, models in the study sites in 2020 is shown in Table 3 in 2020. The soil loss generally differed significantly ($P < 0.05$) among sites and season. The soil loss estimated by empirical model was significantly ($P < 0.05$) higher at Piku followed by Dam, Kigir, Mandaragrau, Gunda and Mirnga. The RUSLE 2 predicted soil loss was significantly ($P < 0.05$) higher at Piku (447.00 kg ha⁻¹ yr⁻¹), Kigir (330.00 kg ha⁻¹ yr⁻¹), Dam (307.00 kg ha⁻¹ yr⁻¹), Mandaragrau (292.00 kg ha⁻¹ yr⁻¹), Mirnga (269.00 kg ha⁻¹ yr⁻¹), and Gunda (260.00 kg ha⁻¹ yr⁻¹) respectively. The respective range for empirical and RUSLE 2, models was 168.38 – 337.00 and 260.00 – 447.00 kg ha⁻¹ yr⁻¹. The soil loss measured by empirical model was significantly ($p < 0.05$) higher at Piku followed by Dam and Kigir then Mandaragrau, Gunda and Mirnga sites with their respective values at 337.10, 227.58, 224.71, 193.49, 184.88 and 168.38 Kg ha⁻¹ yr⁻¹, in the study sites.

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 (Table, 2) 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)

Table 3: Annual Soil Loss Estimated by Empirical and RUSLE2 Models ($\text{Kg ha}^{-1}\text{yr}^{-1}$),

Study Site	Empirical model	RUSLE2 model
Piku	337.39A	447.00A
Kigir	224.71C	330.00B
Dam	227.58B	308.00C
Mirnga	168.38F	269.00E
Mandaragrau	193.49D	292.00D
Gunda	184.88E	260.29F
SE 0.05	0.107	0.108

Source: 2020

Key: SE = Standard error.

Mean followed by the same letter (s) in column are not significantly different at $p < 0.05$

Annual Validation of Soil Loss in Biu Area

Figure 1 shows the performance of RUSLE2 and empirical models in predicting soil loss in the entire study area in 2020. The model recorded the r^2 value of 0.8553. The RUSLE2 model prediction accuracy in Biu area, in terms of soil loss was 85.53. 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 Hortonian overland flow. This observation concurs with the report of 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 Hortonian overland flow.

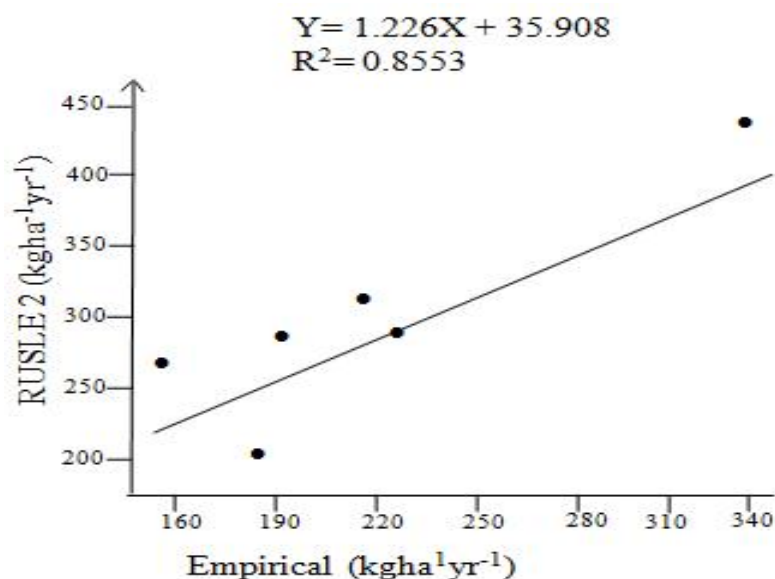


Figure 1: Annual validation of soil loss using aggregate empirical and RUSLE2, estimates in the study area.

Nutrient Loss

Table 4 shows soil nutrient loss at various sites in Biu area in 2020. Soil organic matter loss ranged from 2.01 to 3.80 $\text{kg ha}^{-1}\text{yr}^{-1}$. The soil organic matter loss was significantly ($p < 0.05$) higher at Piku followed by Kigir, Mirnga, Gunda, Mandaragrau and Dam sites with their respective values at 3.80, 2.72, 2.36, 2.35, 2.24 and 2.01 $\text{kg ha}^{-1}\text{yr}^{-1}$. The soil organic matter loss across sites was higher than N, P, K losses. This observation concurs with the report of Schick *et al.*, 2000; Ali *et al.*, 2007;

Lemma *et al.*, (2017) that the loss of organic matter in sediments was higher followed by the loss of N, P, K. Nitrogen loss at various sites ranged from 1.37 to 2.69kg $\text{ha}^{-1}\text{yr}^{-1}$.

Table 4: Soil Nutrients Loss at Various Sites in Biu Area

Site	O.M	N	P	K	Ca	Mg	S
Kg$\text{ha}^{-1}\text{yr}^{-1}$							
Piku	3.82A	2.22A	1.95A	2.72A	2.35A	1.49E	1.02E
Kigir	2.72B	1.48B	1.34B	1.82B	1.69B	1.62D	1.69B
Dam	2.01E	1.14E	1.94A	1.22F	1.29F	1.72A	1.85A
Mirnga	2.35C	1.34C	1.20C	1.69C	1.61C	1.74A	1.62C
Mandaragrau	2.24D	1.22D	1.02E	1.47E	1.37E	1.66C	1.08D
Gunda	2.36C	1.21D	1.11D	1.54D	1.44D	1.68B	1.64C
SE_{0.05}	9.851	9.400	0.010	1.972	6.266	8.650	7.058

Source: 2020

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 $p < 0.05$

Soil and Nutrient Loss

Table 3 and 4 depicted annual soil and nutrients loss at various sites in Biu Area in 2020. Soil loss was significantly ($P < 0.05$) higher at Piku with corresponding nutrients losses in the form of organic matter (O.M), nitrogen, Phosphorus, Potassium, Calcium, Magnesium and Sulphur, followed by Kigir, Dam, Mandaragrau, Mirnga and Gunda sites. Soil and nutrients losses at Piku site were recorded at 447.00, 3.80, 2.20, 1.95, 2.72, 2.35, 1.49 and 1.02 Kg $\text{ha}^{-1}\text{yr}^{-1}$, respectively. Gunda site had soil O.M, N.P.K, Ca, Mg and S losses at 260.00, 2.36, 1.21, 1.11, 1.54, 1.44, 1.68 and 1.64Kg $\text{ha}^{-1}\text{yr}^{-1}$, respectively. This observation concurs with the report of Schick *et al.*, (2000); Ali *et al.*, (2007); Lemma *et al.*, (2017) that the loss of organic matter in sediments was higher followed by loss of K, N, and P.

CONCLUSION AND RECOMMENDATION

The extent 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 were significantly ($p < 0.05$) higher at Piku followed by Kigir, Mirnga, Mandaragrau, Gunda and Dam 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 RUSLE2 model surpassed with greater strength of prediction accuracy than empirical model.

Concerning management strategies to reduce soil and nutrients losses, intervention will focus on the slope length and steepness, conservation management factor and support practice factor as the erodibility and runoff factor cannot be changed. Based on the results of this study, the following recommendations were made:

i. Mulching; - mulch is any layer of material applied to the surface of the soil to protect the soil from the erosion and evaporative effects of wind and sun. Mulch can be plant material, like straw and wood chips or it can be gravel or non – living material like recycled glass, cinders, decorative rock and recycled rubber.

ii. Cover Crops and Vegetation; - cover crops increase soil health improves soil structure and reduces the need for costly inputs such as fertilizer and mechanical tillage. Cover crops protect water quality by slowing erosion and runoff and increases water infiltration and retention.



iii. No tillage method; - in zero tillage, the land for crop cultivation is left undisturbed from harvest to planting or not ploughed at all while in the case of minimum tillage, just holes for planting are made and only at the places where the crop is going to be planted or grain sown. A combination of no tillage with crop residue mulch is more effective in runoff and erosion control

iv. Buffer Zones; - buffer zone increases the capture of sediments and organic materials. It is revealed that buffer zone increase the trapping of sediments and infiltration from 10 to 90 %. Vegetative buffers decrease the runoff velocity of water.

v. 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.

vi. 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.

vii. Check Dam; - check dams are structures constructed across a channel or a river to lesson water velocity and to catch sediments.

viii. Anti – erosive ditches; -an anti – erosive channel is a drainage channel constructed to prevent runoff water from upper hill to enter a cropped land. In this channel, water may infiltrate or may be diverted.

ix. 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.

x. 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.

xi. 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.

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