North American Open Agriculture & Soil Science Research Journal
Vol. 1, No.1, October 2014, pp. 1 - 9
Available online at http://narpub.com/Journals.php

Research article

Comparative Estimation of Measured and Empirical Soil Loss from Ephemeral Gully Erosion in Mubi, Northeast Nigeria

***I.J. Tekwa[1], A.B. Alhassan[2] and F. Fali[1]**

[1]Department of Agricultural Technology, Federal Polytechnic, P.M.B 35, Mubi, Adamawa State
[2]Department of Soil Science, University of Maiduguri, P.M.B 1069, Maiduguri, Borno State

E-mail: jasini.john@yahoo.com

ABSTRACT

A 2 year field study was carried out in Mubi area to assess soil loss from ephemeral gully (EG) erosion at 6 different locations (Digil, Vimtim, Muvur, Gella, Lamorde and Madanya) between April, 2008 and October, 2009. Each location consisted of three watershed sites from where data were collected during the study period. Land use and conservation practices were noted, while EG channel parameters (length, width, depth and shape) were measured at each site. Physico-chemical properties of the soils were determined in field and laboratory using prescribed procedures. Soil loss was measured and empirically predicted. Results showed that the soils were heterogeneous and lying on flat to hilly topography with few grasses, shrubs and trees. Soils were mainly sandy with considerable silt and clay contents. The exchangeable K, Ca, Na and Mg contents were low to high. The measured and empirical area of soil loss (ASL) ranged from 168.93 - 597.43 m^2 and from 181.80 - 350.32 m^2 respectively in 2008, while it was respectively from 70.02 - 426.78 m^2 and 158.42 - 437.98 m^2 in 2009. The measured volume of soil loss (VSL) ranged from 73.42 - 328.61 m^3, while the empirical estimates had lower range of 86.89 - 292.33 m^3, respectively in 2008. The VSL also ranged from 90.06 - 311.91 m^3, and from 85.43 -346.98 m^3 in respect of measured and empirical estimates in 2009. Hence, the measured mass of soil loss (MSL) was 98.78 - 446.33 kg/ac compared to a range of 112.78 - 383.72 kg/ac for empirical estimates in 2008. The MSL was 114.46 - 397.89 kg/ac and 106.82 - 447.11 kg/ac in terms of the actual and empirical erosion in 2009. The measured was generally comparable with the empirical soil loss. Both measured and empirical ASL was higher at Muvur in 2008 and lower at Lamorde and Madanya in 2008 and 2009 respectively. The empirical soil loss was slightly over or under estimated. Future researches are recommended to apply these suitable empirical models as cheaper alternative to field measurement or scarce physically based models in erosion studies in Mubi area.

Key words: Soil loss, Estimation, Measured, Empirical, Ephemeral-gully, Mubi, Northeast-Nigeria

---

INTRODUCTION

Despite the recent global emphasis on ephemeral gully (EG) erosion (concentrated flow channels) as one of the dominant contributors to total soil loss on agricultural fields that largely deprive farmers of significant area of cultivable farmlands (Foster, 2005; Gordon *et al.*, 2007), yet, there is dearth of information on its extent particularly in the study area at present, except for the few empirical studies performed on sheet, rill, and classical gullies (Ekwue and Tashiwa, 1992; Tekwa and Usman, 2006; Tekwa *et al.*, 2014). Several empirical erosion prediction models such as the universal soil loss equation (USLE) and its revised version (RUSLE) (Wischmeier and Smith, 1978) are widely used to estimate soil erosion and to select conservation and management practices for erosion controls, but USLE technology does not estimate EG erosion. Other models patterned after the USLE such as the soil loss estimation model for South Africa (SLEMSA) (Elwell, 1977; Elwell and Stocking, 1982) and a field model for chemicals, run-off, and erosion from agricultural management systems (CREAMS) (USDA-ARS, 1980) among other methods. Development of empirical tool(s) for soil loss studies that could guide as policy and advisory notes to farmers and government in order to forestall erosion development are not sufficiently available. Hence, adoption of statistical data on the extent and severity of soil erosion from other regions are questionable due to wide range of methods of data collection and extrapolation (Lal, 2001). The desire to bridge this information gap is imminent in this part of the World, and therefore the abounding challenges for formulating efficient tools that could predict the pattern and rates of soil loss remain crucial as it may greatly assist policy makers in the drive to curb erosion problems.

Mubi region is a location that is particularly prone to water erosion due to its terrain and long dry periods followed by heavy rainfalls acting on steep slopes with low vegetation cover making the generally sandy clay loam soils in the area to be fragile and erodible (Ekwue and Tashiwa, 1992). In view of this erosion scourge, there is therefore the need to develop suitable empirical tool(s) that could predict the scale and magnitude of erosion development in terms of actual and expected rates of area of soil loss (ASL), volume of soil loss (VSL), and mass of soil loss (MSL) in the study area (Tekwa *et al.*, 2014). This research therefore, is aimed at assessing the performance of predictive tool (empirical equation) in relation to measured soil loss estimates in the study area.

The Study area

The 6 study sites are located in Mubi local government areas-(Mubi North (Digil, Vimtim, and Muvur) and Mubi South (Gella, Lamorde and Madanya)) in the state of Adamawa in northeast Nigeria (Fig. 1). The sites were selected based on their land use, topography, vegetation cover and soil type. The climate of the area was that of typical wet and dry seasons. The dry season runs from November to April, while the wet season runs from May to October. The average annual rainfall amount ranges from 700 mm to 1,050 mm (Udo, 1970; Adebayo, 2004). The driest months are March and April. The average minimum temperature is 15.2 ^{o}C in December and January, while the maximum temperature occurs in April (Adebayo and Tukur, 1999). Grasslands with scattered trees typical of a savannah region are the dominant vegetation (Adebayo and Tukur; 1999; Adebayo, 2004; Tekwa and Usman, 2006). Land use types in the area are mixed farming that involves cattle rearing and arable farming systems, which are persistently confronted by erosion problems.

METHODOLOGY

Soil sampling and analysis

Eighteen composite soil samples were collected during each growing season of the two year study. A soil sample was collected from each of the 3 EG selected at each of the 6 sites studied. Soil samples were collected using a bucket soil auger at 0 -15 cm depths in a transverse direction, when the soils were relatively moist and bulked. Each composite soil sample was stored in a plastic bag. The samples were air-dried, crushed and sieved through a 2 mm sieve, before test for determination of the selected physical and chemical properties.

Determination of soil physical properties

The particles size distribution was determined using the Bouyocous hydrometer method (Trout et al., 1987). The bulk density was determined by the clod method (Wolf, 2003), while the water holding capacity was measured by gravimetric water content of a given quantity of soil fully saturated with water (Trout *et al*., 1987).

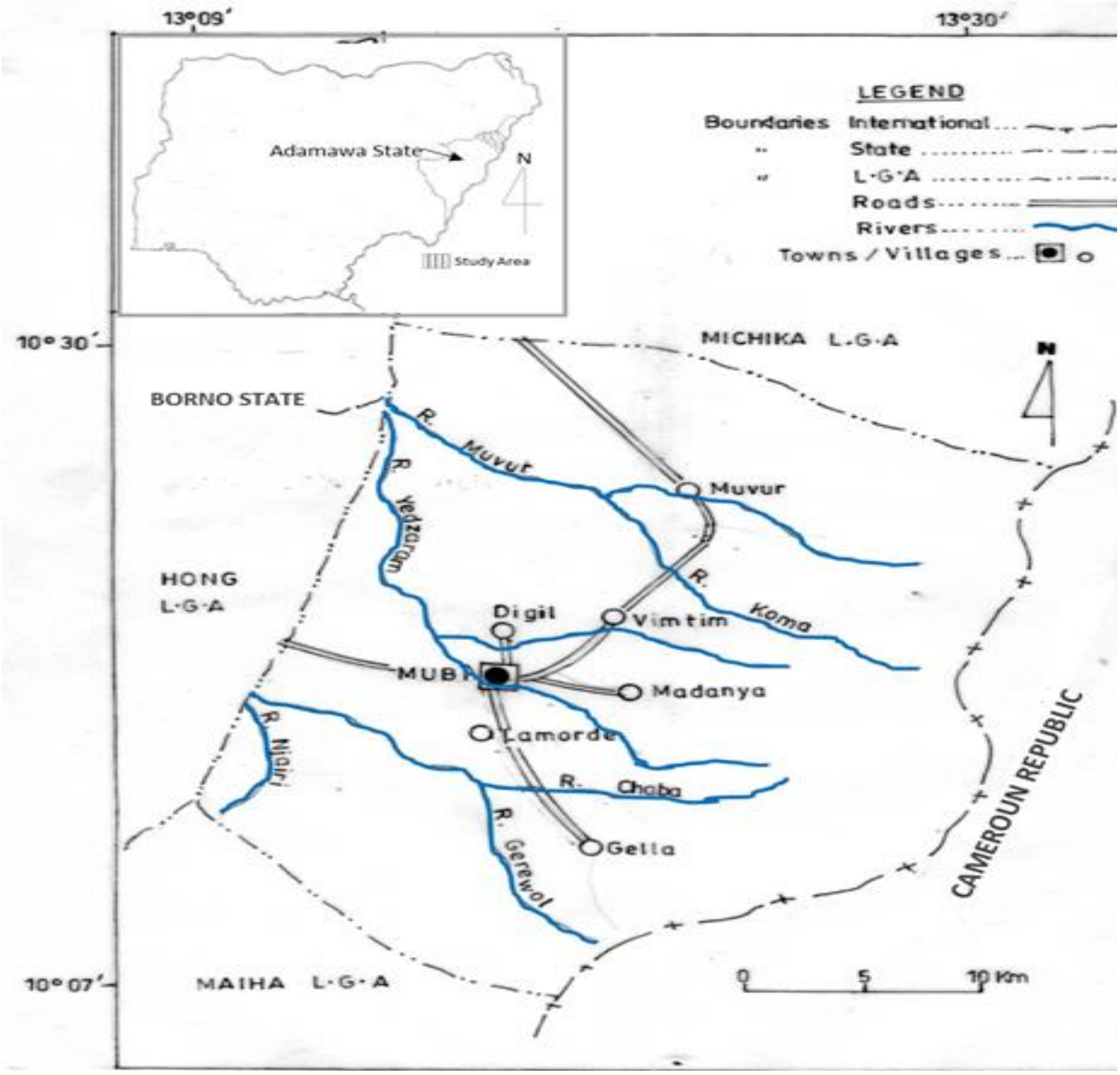

Figure 1: Map of the study area showing study locations (farm sites) Adapted from Tekwa *et al.* (2014).

Determination of soil chemical properties

The organic carbon (OC) content was determined using the potassium dichromate wet-oxidation method of Walkley and Black (1934). The O.C content was converted to organic matter (OM) content by multiplying with a factor of 1.724 (Wolf, 2003). The exchangeable calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+) and sodium (Na^+) were extracted using Ammonium Acetate (1 N; pH 7.0). The exchangeable Ca^{2+} and Mg^{2+} were later measured by titrimetric method, while the exchangeable K^+ and Na^+ were measured using flame photometry (Jackson, 1965). The total exchangeable base (TEB) was computed as a summation of exchangeable bases. The chemical properties were rated in accordance with Aduayi *et al.* (2002).

Determination of daily rainfall amounts in the study area

The 24-h rainfall amount in the study area was sourced from the Adamawa state University meteorological station, Mubi in 2008 and 2009, and as presented

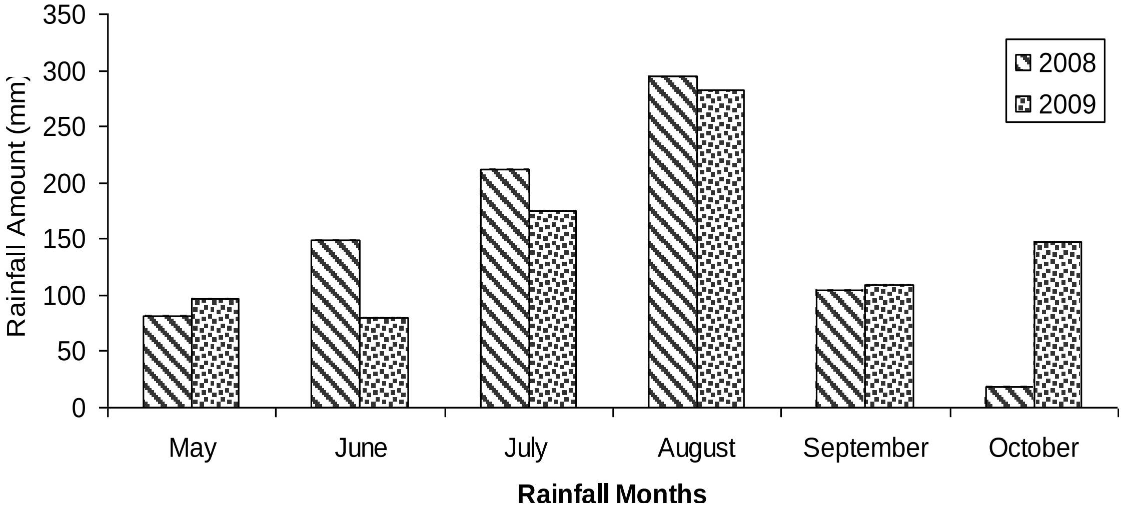

Figure 2: Total amount of 24-h rainfall received in May - October each year (2008 & 2009) in Mubi area Adapted from Tekwa *et al.* (2014).

Determination of measured soil loss in the study area

The measured (actual) soil loss was determined using mathematical expressions as presented below:

i) Area of soil loss (ASL)

The area of EG cylindrical shaped = $2\pi r l_2 - 2\pi r l_1$

where: r = radius of a cylindrical EG shape

l = length of EG feature

π = constant of proportion

The area of EG cone shaped = $\pi r^2 h_2 - \pi r^2 h_1$

where: r = radius of an EG head-cut area

h = perpendicular height of EG head from an imaginary axis (5 m adopted)

Total ASL = Net area of EG cylinder shaped + Net area of EG cone shaped

ii) Volume of soil loss (VSL)

Volume of soil loss (VSL_2-VSL_1) of EG cone shaped = $\frac{1}{3}\pi r^2 h_2 - \frac{1}{3}\pi r^2 h_1$

where: h = perpendicular height of gully head (cone shaped)

r = radius of an EG head-cut (Cone shaped)

Volume of soil loss along EG cylinder shaped = $\frac{1}{2}\pi R^2 l_2 - \frac{1}{2}\pi R^2 l_1$

where: R = radius of gully basin (cylinder-shaped)

l = length of gully basin

h = EG incision depth (cylinder shaped)

Total VSL (T_{vl}) = Net VSL (EG cone shaped) + Net VSL (EG cylinder shaped)

iii) Mass of soil loss (MSL) = VSL × soil bulk density (δ_b)

Determination of empirical soil loss in the study area

The empirical model adapted in this study was a linear equation earlier developed from quantitative field data and a multiple regression analysis (equation 1) earlier developed in the study area (Tekwa *et al.*, 2013). The regression equation is expressed as: -

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \cdots + \beta_8 X_8 \qquad (1)$$

where: Y = estimate of soil loss

α and β = regression parameters

X_1 = soil bulk density,

X_2 = Clay content,

X_3 = soil erodibility index,

X_4 = soil plasticity index,

X_5 = organic matter content,

X_6 = soil shear strength,
X_7 = site slope rate,
X_8 = volume of run-off water

The adapted empirical models (Tekwa *et al.*, 2013) used for predicting soil loss in the area are presented in equations 2 - 4.

Y_{ASL} = 3166.40 - 2087.82 (δ_b) - 7.20977 (clay) + 419.453 (SEI) + 13.2948 (PL) - 133.601 (OM) - 7109.39 (τc) + 2.90245 (SR) + 480.420 (Run-off); r^2 = 0.3997 -- - - -- (2)

Y_{VSL} = 2170.98 - 1556.63 (δ_b) - 4.8032 (clay) + 868.765 (SEI) + 13.0510 (PL) - 102.693 (OM) - 5322.86 (τc) + 4.75836 (SR) + 199.491 (Run-off); r^2 = 0.9515 - - - - - (3)

Y_{MSL} = 2666.99 - 1899.59 (δ_b) - 6.93032 (clay) + 1124.52 (SEI) + 17.2004 (PL) - 136.544 (OM) - 7011.92 (τc) + 6.60113 (SR) + 284.778 (Run-off); r^2 = 0.9388 - - - - - (4)

where, Y_{ASL} = predicted area of soil loss,
Y_{VSL} = predicted volume of soil loss,
Y_{MSL} = predicted mass of soil loss,
δ_b = bulk density,
Clay = clay content,
SEI = erodibility index,
PL = plasticity index,
OM = organic matter content,
τc = shear strength,
SR = site slope rate,
Run-off = volume of run-off water,
r^2 = coefficient of determination

Data analysis

The data collected was analyzed using the generalized linear model in a randomized complete block design for the ANOVA (Statistix 9.0, version 2012). The results were compared using student t-test.

RESULTS AND DISCUSSION

Field characteristics of the study area

The field characteristics were heterogeneous in nature with EG channels having “V” and “U” shapes resulting from seasonal channel incisions by run-off water on a rolling terrain. Ekwue and Tashiwa (1992) and Tekwa and Usman (2006) reported similar topographic features on EG channel sites earlier investigated in the Mubi area. Fewer grasses and trees were noted at Vimtim and Digil, and were perhaps influenced by agricultural tillage activities. Other sites such as Gella (20 - 22% slope) and Lamorde (18 - 20% slope) that are typically mountainous topography were noted for little arable activities with denser shrub and grass vegetations (Tekwa *et al.*, 2013). These features perhaps curtailed soil loss on the mountainous (Gella and Lamorde) watersheds. Even though, several conservation practices exist, ranging from vegetative barriers, terraces, and tied - ridges and rough tillage as controls at sites with moderate or rolling topography. The soils were sandy clay loamed, except Gella with sandy loam textures (Table 2), comprising high sand (50.30 - 62.41%) with silt and clay fractions in the range of 18.06 - 24.57 and 19.53 - 26.47%) respectively, and which did not differ significantly ($P<0.05$) among sites over the study period.

Table 1: Field characteristics Adapted from Tekwa *et al.* (2013)

Site description	EG channel shape	Topography (slope) (%)	Cover condition	Conservation practice
Digil	V	0 – 4 (very flat-to-gentle)	Cultivated land with few grasses, shrubs and trees	scanty vegetative barriers, tied-ridging
Vimtim	U	4 - 6 (moderate to flat-to-gentle)	Cultivated land with few grasses and trees	Rough surface tillage, tied ridging
Muvur	U	6 – 8 (moderate or rolling)	Cultivated land with few grasses and trees	tied-ridging
Gella	V	20 – 22 (mountainous hilly or steep)	Cultivated land with few trees, grasses and shrubs	Terraces, sand-bags, Stone lines
Lamorde	U	18 – 20 (mountainous hilly or steep)	Cultivated land with few trees, shrubs and grasses	Terraces, sand-bags, Stone lines
Madanya	U	4 - 8 (moderate to flat-to-gentle)	Cultivated land with few grasses and shrubs	Dence vegetative barriers, tied ridging

Table 2: Texture and some chemical properties of soils of the study area

Soil Parameter	Study sites					
	Digil	Vimtim	Muvur	Gella	Lamorde	Madanya
Sand (%)	53.61	59.19	51.88	62.41	51.96	50.30
Silt (%)	19.92	18.05	22.16	18.06	24.57	24.29
Clay (%)	26.47	22.76	25.96	19.53	23.47	25.41
Texture	SCL	SCL	SCL	SL	SCL	SCL
Organic matter content (%)	0.76	0.91	1.13	0.88	1.31	1.17
Exchangeable potassium (Cmol(+)/kg)	3.56	2.39	3.27	3.67	10.03	4.60
Exchangeable calcium (Cmol(+)/kg)	15.65	14.35	15.82	9.49	16.78	19.68
Exchangeable magnesium (Cmol(+)/kg)	2.44	4.28	4.69	3.96	6.98	10.59
Exchangeable sodium (Cmol(+)/kg)	0.79	1.01	0.85	0.85	1.16	0.97
Total exchange basis (Cmol(+)/kg)	22.44	22.02	24.64	17.97	34.94	35.85

Key: SCL = sandy clay loam; SL = Sandy loam. Adapted from Tekwa *et al.* (2013)

The soils were likely formed under relatively uniform environmental conditions (Brady and Weil, 2002, and Oygarden, 2003). Yair and Lavee (1985) noted that increased sandiness occurs when selective migration of finer particles in soils happens, such that the coarse particles become progressively coarser.

On the other hand, the mean soil chemical properties revealed that soil organic matter was low ranging, and inadequate to have reduced erosion losses in the study area. The basic cations (K, Ca, Mg, and Na) known for abating erosion (Lal, 2001), significantly ($P<0.05$) differed in the study sites, where exchangeable K was consistently very high, while Ca and Na contents were rated as moderate to high, and to very high in terms of Mg saturation, especially at Lamorde and Madanya sites. This perhaps explains why soil loss was minimal at Madanya site with comparably higher estimates of OM, Ca, Mg and TEB (Table 2), in addition to established vegetative barriers (Table 1). These soil properties are widely reported in mitigating erosion on most agricultural fields (Lal, 2001).

Measured versus empirical estimates of soil loss in the study area

The results of comparison between measured and empirical ASL, VSL, and MSL are presented in Table 3. The results revealed that the measured ASL ranged from 168.93 - 597.43 m^2, while it was from 181.80 - 350.32 m^2 in respect of empirical estimates in 2008. The empirical soil erosion expressed both under and over prediction behavior. Though, there were no differences between the measured and empirical erosion in 2008, except at Muvur. The erosion was over predicted at Digil (98.12 m^2), Vimtim (16.68 m^2) and Lamorde (43.38 m^2), while it was under predicted at Muvur (247.10 m^2), Gella (69.99 m^2) and Madanya (35.73 m^2) in 2008. Conversely, in 2009, the measured ASL ranged from 70.02 - 426.78 m^2, while empirical ASL ranged from 158.42 - 437.98 m^2 actual erosion in this study. The actual erosion was not significantly ($P<0.05$) different from the empirical estimates in this study. This implies that the developed empirical model appears as suitable alternative to the rigorous field measurement of erosion, as well as sourcing and application of the very scarce physically based models mostly formulated under different climates and/or regions.

Table 3: Comparison between measured and empirical soil loss in the study sites

Study location	Seasonal soil loss					
	Measured	Empirical	T- test	Measured	Empirical	T- test
	2008			2009		
			Area of soil loss (m^2)			
Digil	214.38	312.50	-98.12^{ns}	266.06	275.64	-9.58^{ns}
Vimtim	325.60	342.28	-16.68^{ns}	306.37	308.11	-1.74^{ns}
Muvur	597.43	350.32	247.10*	343.12	437.98	-94.86^{ns}
Gella	376.03	306.04	69.99^{ns}	426.78	253.98	172.80^{ns}
Lamorde	168.93	212.33	-43.38^{ns}	70.02	335.16	-265.14^{ns}
Madanya	217.52	181.80	35.73^{ns}	133.14	158.42	-25.28^{ns}
			Volume of soil loss (m^3)			
Digil	161.35	204.33	-42.98^{ns}	184.25	188.09	-3.84^{ns}
Vimtim	328.61	278.98	49.63^{ns}	278.11	273.46	4.64^{ns}
Muvur	299.06	292.33	6.73^{ns}	311.91	346.98	-35.08^{ns}
Gella	115.34	134.44	-19.09^{ns}	151.24	116.11	35.13^{ns}
Lamorde	144.84	141.33	3.51^{ns}	179.16	198.88	-19.71^{ns}
Madanya	73.42	86.89	-13.47^{ns}	90.06	85.43	4.62^{ns}
			Mass of soil loss (kg/ha)			
Digil	227.50	276.63	-49.14^{ns}	258.51	255.26	3.25^{ns}
Vimtim	446.33	372.19	74.14^{ns}	344.49	364.08	-19.59*
Muvur	400.19	383.72	16.47^{ns}	397.89	447.11	-49.22^{ns}
Gella	154.23	180.75	-26.51^{ns}	200.63	149.46	51.17^{ns}
Lamorde	196.20	188.07	8.14^{ns}	228.67	260.38	-31.71^{ns}
Madanya	98.78	112.78	-14.00^{ns}	114.46	106.82	7.64^{ns}

Key: ns = difference between means are not significant ($P<0.05$)
* = difference between means are significant ($P<0.05$)

Results of comparison between measured and empirical VSL estimates showed that the measured soil loss ranged from 73.42 - 328.61 m^3, while the empirical estimates occurred within lower range of 86.89 - 292.33 m^3, respectively. The results indicated slight over and under prediction of empirical VSL in contrast to the measured erosion. In 2008, the empirical VSL was over predicted at Digil, Gella, and Madanya by 42.98, 19.09 and 13.47 m^3 respectively, while it was comparably under predicted at Vimtim, Muvur, and Lamorde by 49.63, 6.73, and 3,51 m^3 respectively. The measured VSL ranged from 90.06 - 311.91 m^3, compared to a range of 85.43 -346.98 m^3 in respect of empirical estimates in 2009. It was observed that the empirical VSL was slightly over predicted at Digil, Lamorde, and Muvur by 3.84, 19.71 and 35.08 m^3 respectively, while it was under predicted at Vimtim, Madanya, and Gella by 4.64, 4.62 and 35.13 m^3 respectively. On the other hand, the VSL was under predicted at Vimtim, Gella, Digil, and Lamorde by 108.91, 106.15, 51.91 and 40.92 m^3 respectively. It was observed that there were still no wide differences between measured and empirical VSL. The erosion (VSL) severity was relatively intense at Muvur, than at other sites. Both measured and empirical VSL were lower at Madanya. It was still observed that the measured VSL estimates were widely similar to the empirical soil loss. This also implies that the developed empirical tool may redress the problem of non compatibility of erosion results from other regions (Lal, 2001). This relationship was however; an expected outcome due to the fact that actual estimates are more related to empirical, than with especially physically based models (Tekwa *et al.*, 2014; Nasri *et al.*, 2008). This was earlier reported by Nachtergaele *et al.* (2001a & b), that comparing predicted volume with measured ones generates a spurious self-correlation. On the other hand, the empirical erosion was slightly over and under predicted, which were generally under predicted in the sites, except at Muvur in 2009, and at Madanya in both years. The wide under prediction of VSL was also reported in several other works (Nasri *et al.*, 2008; Capra *et al.*, 2004; Nactergaele *et al.*, 2001a).

Results of MSL in 2008 showed that when the empirical estimates were compared with the measured (actual) soil loss, it was slightly over predicted by 49.14, 26.51, and 14.00 kg/ac, respectively at Digil, Gella, and

Madanya, while it was under predicted by 74.14, 16.47, and 8.14 kg/ac at Vimtim, Muvur, and Lamorde respectively. There were no significant (P<0.05) differences between measured and empirical MSL. The actual erosion (MSL) severity occurred in the order: Vimtim (446.33 kg/ac) ≥ Muvur (400.19 kg/ac) > Digil (227.50 kg/ac) ≥ Lamorde (196.20 kg/ac) ≥ Gella (154.23 kg/ac) > Madanya (98.78 kg/ac) within a range of 98.78 - 446.33 kg/ac. The empirical MSL was in the order: Muvur (383.72 kg/ac) ≥ Vimtim (372.19 kg/ac) > Digil (276.63 kg/ac) > Lamorde (188.07 kg/ac) ≥ Gella (180.75 kg/ac) > Madanya (112.78 kg/ac) within a range of 112.78 - 383.72 kg/ac. Conversely, the empirical MSL was over predicted by 49.22, 31.71, and 19.59 kg/ac at Muvur, Lamorde, and Vimtim respectively, while it was under predicted by 51.17, 7.64 and 3.25 kg/ac respectively at Gella, Madanya, and Digil in 2009. There were no significant (P<0.05) differences between measured and empirical MSL at all sites in both years, except at Vimtim. The MSL ranged from 114.46 - 397.89 kg/ac in terms of actual erosion. On the other hand, the empirical erosion severity was in the order: Muvur (447.11 kg/ac) ≥ Vimtim (364.08 kg/ac) > Lamorde (260.38 kg/ac) ≥ Digil (225.26 kg/ac) > Gella (149.46 kg/ac) ≥ Madanya (106.82 kg/ac) within a range of 106.82 - 447.11 kg/ac. The empirical MSL estimates were slightly over or under predicted, but without significant (P<0.05) differences. The observed trend was perhaps due to the strength of empirical models to predict actual soil loss, than especially physically-based models as earlier emphasized by Capra *et al.* (2004), Foster *et al.* (2004), Nasri *et al.* (2008) and Nachtergaele *et al.* (2001 a & b) among other authors.

SUMMARY AND CONCLUSION

Empirical estimates of ASL, VSL, and MSL were generally over or under predicted, but were widely without significant (P<0.05) differences from the actual erosion. Both measured and empirical ASL were significantly (P<0.05) higher at Muvur and lower at Lamorde and Madanya respectively in 2008 and 2009. Both soil loss types showed repeated pattern of erosion in terms of VSL and MSL estimates at all sites, regardless of season. Generally, soil erosion occurred at all sites and was significantly (P<0.05) higher at unprotected soils of Muvur and lower at Madanya with protective vegetative barriers, regardless of the applied soil loss prediction tool, which performed similarly in this study.

RECOMMENDATIONS

Farmers, land policy formulators, prospective researchers, students, and other corporate and government agencies, should apply the newly developed and efficient empirical model (Tekwa *et al*., 2013) for predicting ASL, VSL, and MSL as a cheap alternative to field measurement of erosion in Mubi and environs. Future empirical prediction of soil loss should consider modeling equations that could compute soil loss on monthly basis. Hence, agronomic and cultural practices such as tied ridging, terraces, and vegetative barrier establishments that could reduce EG depths, widths, lengths, and other erosion processes are strongly recommended.

REFERENCES

[1] Adebayo A.A. (2004). Mubi Region: A Geographical Synthesis (1st Ed.) Paraclete Publishers, Yola-Nigeria. Pp 32-38.
[2] Adebayo A.A. and Tukur A. L. (1999). Adamawa State in Maps (1st Ed.). Department of Geography F.U.T. Yola. Pp 92.
[3] Aduayi E.A., Chude V.O., Adebusuyi B.A. and Olayiwola S.O. (2002). Fertilizer use and management pratices for crops in Nigeria (3rd Ed.). Federal Fertilizer Department, Federal Ministry of Agriculture and Rural Development, Abuja. S.B. Garko International Limited. pp 28.
[4] Brady N.C. and Weil R.R. (2002). The nature and properties of soils (13th edition). Pearson Educ. Pub. New Delhi, India.
[5] Capra A., Mazzara L.M. and Scicolone B. (2004). Application of the Ephemeral gully Erosion model to predict ephemeral gully erosion in Sicily, Italy. Elsevier. Catena. Vol. 59(2):1-13.
[6] Capra A. and Scicolone B. (2002). Ephemeral gully erosion in a wheat cultivated area in Sicily (Italy) Biosystems Engineering. Vol. 83. Scopus, Sicily, Italy.
[7] Ekwue E.I, and Tashiwa Y.I. (1992). Survey of gully erosion features in Mubi local government area of Adamawa State. Annals of Borno. 8/9:181-191.
[8] Elwell H.A. (1977). Soil loss estimation for southern Africa. Research Bulletin 22. Department of Conservation and Extension: Harare, Zimbabwe.

[9] Elwell H.A, Stocking M.A. (1982). Developing a simple yet practical method of soil loss estimation. Tropical Agriculture 59: 43-48.

[10] Foster G.R. (1986). Understanding ephemeral gully erosion. Soil conservation, Assessing the National Research Inventory. National Research Council, Board on Agriculture 2. National Academy Press. Washington, DC. Pp 90-118.

[11] Foster G.R. (2005). Modeling ephemeral gully erosion for conservation planning. International Journal of Sediment Res. 20(3): 157-175.

[12] Gordon L.M., Bennett S.J., Bingner R.L.,Theurer,F.D. and Alonso, C.V. (2007). Simulating ephemeral gully erosion in AnnAGNPS. American Society of Agricultural and Biological Engineers 50(3): 857-866.

[13] Jackson M. L. (1965). Soil chemical analysis. Prentice Hall. New-york. USA.

[14] Lal, R. (2001). Soil degradation by erosion. Land Degradation and Development 12: 519-539. John Wiley & Sons Ltd, USA

[15] Nachtergaele J.J., Poeson L., Vandekerckove D., Oostwoud W. and Roxo M. (2001a). Testing the ephemeral gully erosion model (EGEM) for two Mediterranean environments. Earth Surface Processes and Land Forms: 26: 17-30.

[16] Nachtergaele J.J, Poeson, A,, Steegen I., Takken L. Beuselinck L., Vandekereckove G., and Grovers G. (2001b). The value of a physically based model versus an empirical approach in the prediction of ephemeral gully erosion for loss-dierived soils. Geomorphology 40:237-252.

[17] Nasri M., Feiznia, S. Jafari, M., Ahmadi H. (2008). Using field indices of rill and gully in order for erosion estimating and sediment analysis. (Case study: Menderjan Watershed in Isfahan Province, Iran). World Academy of Science, Engineering and Technology. 43:370-376.

[18] Oygarden, L. (2003). Rill and gully development during an extreme winter runoff event in Norway. Catena. 50:217-242.

[19] Statistix 9.0 (2012). Statistical Package for Scientists and Engineers. Analytical softwares- StatistiXL. USA

[20] Tekwa, I.J, Alhassan, A.B, Chiroma, A.M. (2013). Effect of selected erosion predictors on seasonal soil loss from ephemeral gully erosion features in Mubi area, Northeastern Nigeria. Scholarly Journal of Agricultural Science. Vol. 3(10), pp 401-409. Available online at http://www.scho larly-journals.com/SJAS.

[21] Tekwa I.J., Laflen, J.M, Yusuf, Z. (2014). Estimation of Monthly Soil Loss from Ephemeral Gully Erosion Features in Mubi, Semi-arid Northeastern Nigeria. International Research Journal-Agricultural Science Research Journal. 4(3): 51-58. Available online at http://www.resjournals.com/ARJ.

[22] Tekwa I.J. and Usman B.H. (2006). Estimation of Soil loss by gully erosion in Mubi, Adamawa State, Nigeria. Journal of the Environment. Paraclete Publishers Yola-Nigeria. 1(1): 35-43.

[23] Trout T.T., Garcia-castillas, I.G. and Hart, W.E. (1987). Soil Water Engineering Field and Laboratory Manual. M/S Eurasia. New Delhi, India.

[24] Udo R.K (1970). Geographical Reports of Nigeria. (1st ed). Heinemann. London. Pp.195-197.

[25] USDA-Agricultural Research service (ARS) (1980). CREAMS: A field scale model for chemicals, runoff and Erosion from Agricultural management systems. Conservation Research Report No.26.

[26] Walkley A. and Black C. (1934), Chronic acid titration method for determining soil organic matter: Soil Science Society of America Journal. 37:29

[27] Wischmeier W.H. and Smith D.D. (1978). Predicting rainfall erosion losses. USDA Agriculture Handbook. 537.

[28] Wolf B. (2003). Diagnostic techniques for improving crop production. Haworth press. USA.

[29] Yair A. and Lavee H. (1985). Run off generation in arid and semi-arid Zones. In: Hydrological Forecasting, Anderson M.G. and Burt T.P. (eds). John Wiley & Sons: New York. Pp 183-220.