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Research article

Sensitivity Analysis of Some EGEM Inputs in Predicting Ephemeral Gully Erosion in Mubi, Semi-arid Northeast Nigeria

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ABSTRACT

Adaptation trial of ephemeral gully erosion model (EGEM) was carried out under local conditions of Mubi area in 2008 and 2009 wet seasons. Relevant erosion variables were determined and land use characteristics were noted. Sensitivity trials were carried out using observed erosion variables, in addition to adjusted EG depth and length in the EGEM. Results showed that the soils were heterogeneous and lying on flat to hilly topography with few grasses, shrubs and trees. Soils were mainly sandy (50.30 - 62.41%) with silt and clay contents in the range of 18.05 - 24.57 and 19.53 - 26.47% respectively, while the WHC was 18.30 - 28.97%. Sensitivity trials revealed that soil shear strength and bulk density reduced erosion, while increased EG depth, length, and channel erodibility positively correlated with erosion. The adjustment effects of EG depth and length on EGEM predictions corresponded with irregular pattern of soil loss associations. Adjusted depths influenced erosion in 2008 from 16 - 64, 1 - 124, 31 - 197% in terms of area (ASL), volume (VSL), and mass of soil loss (MSL), while it was respectively from 8 - 125, 16 - 109, and 0.2 - 118% in 2009. Also, adjusted lengths influenced erosion by 26 - 68, 2 - 122, and 2 - 127% in respect of ASL, VSL, and MSL in 2008, while it was from 8 - 76, 7 - 101, and 8 - 109%, respectively in 2009. Erosion control that curtails EG depth and length advances are strongly recommended in the study area.

Keywords: Erosion variables, Sensitivity analysis, EGEM, Ephemeral gully, Soil loss prediction, semi-arid Nigeria

INTRODUCTION

The desire for effective technology transfer by most of the underdeveloped countries has remained interestingly unstoppable. The low pace of innovative research works among scientists, especially in such impoverished nations has subjected individuals and/or groups to perform tests on suitable and scarce technologies, such as ephemeral gully erosion model (EGEM) for possible adaptations. Ephemeral gully (EG) erosion is a recently recognized class of water erosion (Foster, 1986), which is a transient feature, lasting only for a short time, and a sediment source that was previously not accounted for alongside rill, sheet, and gully erosion, and which causes irreversible and colossal losses of valuable agricultural land resources (Lal, 2001). Several other water erosion models such as the universal soil loss equation (USLE) and its revised version (RUSLE) (Wischmeier and Smith, 1958) were used to measure surface erosion in the past, but unsuited to EG erosion studies.

Presently, the EGEM remains the only specifically developed and adaptable tool for EG erosion prediction around the World (USDA, 1992; Woodward, 1999; Capra *et. al*, 2004; Nactergaele *et al.*, 2001a,b), despite the newly revised EGEM edition (Gordon *et al.*, 2007). At present, there is no report on EGEM adaptation trial test in the whole of sub-Saharan Africa, particularly Nigeria. The quest to bridge this information gap triggered this research for possible adaptation of EGEM model for erosion studies in Mubi environment.

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).

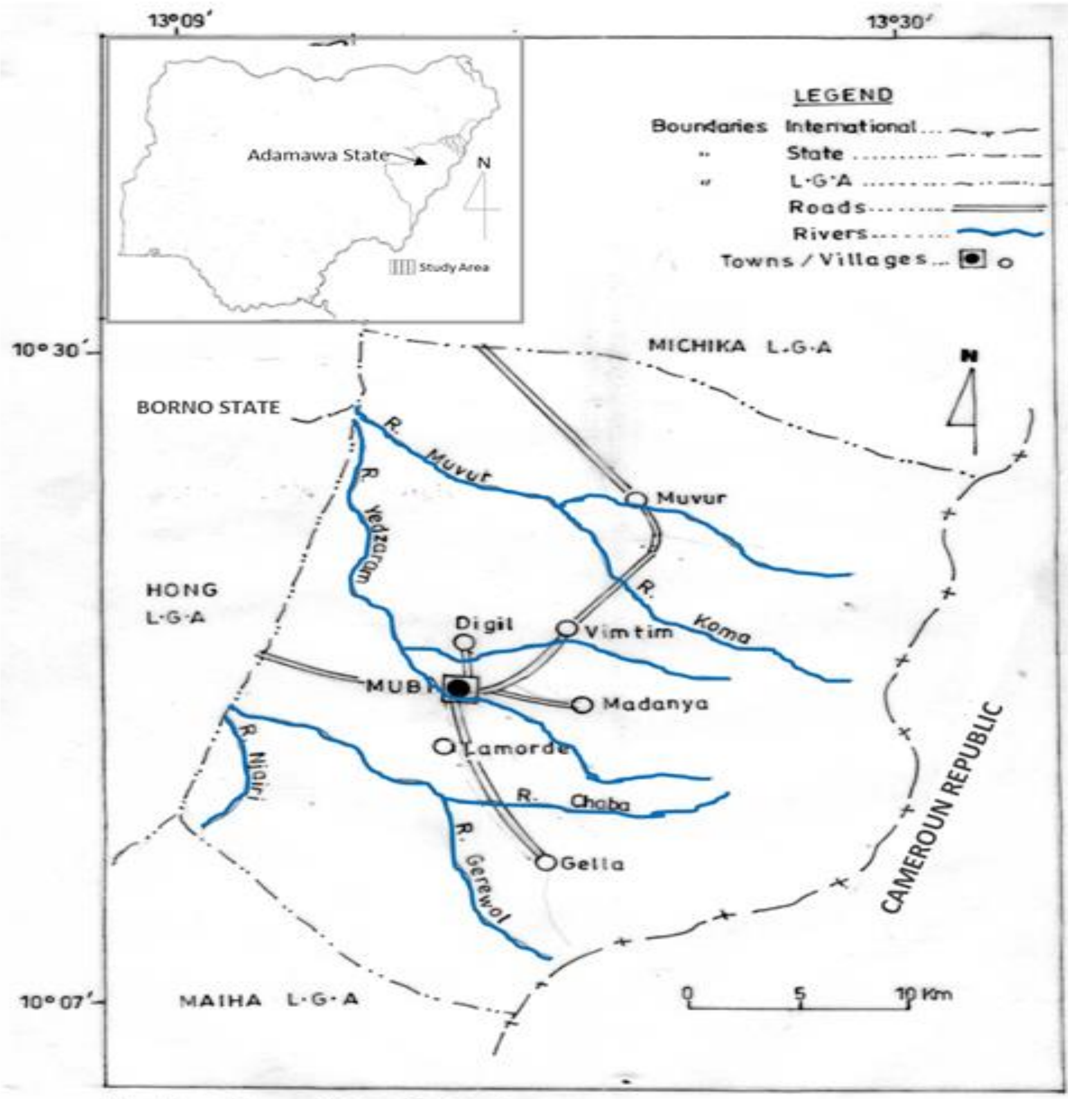

Fig. 1: Map of the study area showing farm sites (villages) Adapted from Tekwa *et al.* (2014).

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 for two years; a soil sample each from the 3 EG features 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 well labeled polythene bag. The samples were air-dried, crushed and sieved through a 2 mm sieve, then prepared and analyzed for 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).

Determination of EGEM Model Input Data

Information on the geography of the study area such as location, climate, topography, altitude, soil map, vegetation, agriculture and human activities constitute the identification components of the EGEM input data. The EGEM program provides entry of data on client, county, state, cultural practice, date and name of the researcher as identification parameters (Foster, 1986). The drainage area was generated using the curve number (CN) values. The Manning roughness coefficient used values for tropical soils (SCS, 1992) based on soil type, clay content, and tillage practices in the study area. The detachment rate of the eroding soil particles was generated by EGEM, while the volume of run-off water received on each EG site was computed from rainfall data supplied to EGEM.

Watershed data such as watershed length (which represents the maximum potential length of the EG) was determined using a field survey with a GPS modem (Nasri *et al*., 2008), while watershed slope was determined using an Abney level (Tolu 2002). Concentrated flow length (actual length of the EG) and the EG maximum depth were measured. EGEM limits maximum EG eroded depth to that of the maximum estimated tillage depth. Depleted width was determined in terms of the difference between the initial and maximum EG depth (Capra *et al*., 2004). The hydrologic soil group was determined in accordance with the United State Department of Agriculture (USDA) method of mapping soil hydrological groups (Philips and Joubert, 2009).

The soil shear strength was computed in accordance with the expression developed by Smerdon and Beasley (1961) given as:

$$TC = 0.0065(10^{\,0.0182 \times \%\ \text{clay})}$$

where TC = critical hydraulic shear

The rainfall data was the sum of the twenty four hour (24-h) rainfall events occurring during the study period. However, EGEM originally used rain storm distribution available in the United States of America (USA). These include types 1,1A, II and III for different climates (Capra *et al.*, 2004).

In this study, the 24-h rainfall was the amount of rainfall received using a manual rain gauge between 9.00 am (the first day) and 9.00 am (the next day) totaling 24 hours duration (Fig. 2). The 2 year 24-h and 25 year 24-h rainfall events, were computed from the expression described by the Pennsylvania State Climatologist (PSC) (2009), expressed as:

$$X = \psi - \beta \ln[-\ln(F)] \qquad (2)$$

where: X = extreme rainfall value

ψ = average - γ β (where γ is Euler's constant, approximately 0.557)

$\beta = 0.78\sigma$ (where σ is the standard deviation)
F = (n - 1)/n (where F is the rainfall event period, and n = number of years)
ln = natural log

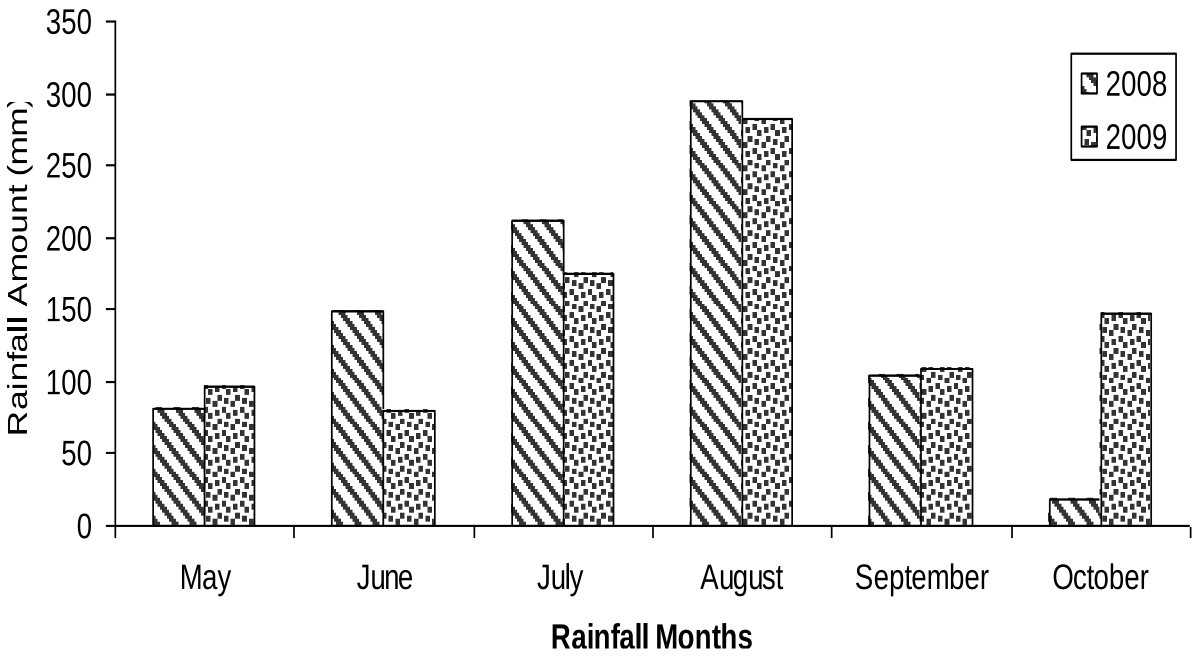

Fig. 2: Total amount of 24-h rainfall received in May - October each year (2008 & 2009) in Mubi area
Adapted from Tekwa *et al.* (2014).

The PEI was determined in accordance with the method described by Lal (1983). The PEI for each EG site was computed in terms of percentage of days with erosive 24-h rainfall (>20 mm) over the total rainfall days in a season, expressed as:

$$\text{PEI} = \frac{\text{Number of erosive 24-h rainfall (>20 mm) days}}{\text{Total number of rainfall days in a year}} \times 100 \quad \text{-- --} \quad (3)$$

The EGEM model software (EGEM version 2.0) estimated soil loss in the study area in terms of voided area (acres) and eroded volume (tons).

Table 1: An overview of EGEM input parameters and method of data collection

Parameter	Method of Data Collection
Drainage area (ha)	Computed by EGEM
Watershed length (m)	GPS $_{\text{Map information analysis}}$ (Nasri *et al.*, 2008)
Concentrated flow length (m)	Field measurement (Nachtergaele *et al.* (2001a)
Maximum ephemeral gully depth (cm)	Field measurement (Nachtergaele *et al.* (2001a)
Ephemeral gully width (m)	Field measurement (Nachtergaele *et al.* (2001a)
Watershed slope (%)	Abney level device (Tolu, 2002)
Concentrated flow slope (%)	Abney level device (Tolu, 2002)
24-h depth (mm)	Manual rain gauge
2 yr 24-h rainfall (mm)	According to Pennsylvania State Climatologists (PSC) (2009)
25 yr 24-h rainfall (mm)	According to Pennsylvania State Climatologists (PSC) (2009)
Soil erodibility index (SEI)	According to Mitchell and Bubenzer (1993)
Percent erosivity index (PEI) (%)	Computed from local rainfall data (Lal, 1983)
Rain distribution type	Local distribution
Tillage practice	Field observation
Bulk density (Mgm^{-3})	Laboratory determination (Wolf, 2003)
Curve number (CN)	Field observation (SCS, 1992)
Manning number (n)	Computed by EGEM
Soil class	Laboratory determination (Trout *et al.*, 1987)
Particle diameter (mm)	Computed by EGEM
Particle specific gravity (Mgm^{-3})	Computed by EGEM
Critical shear stress (Nm^{-2})	Laboratory determination (Laflen *et al.*, 1987)
Peak flow rate (cfs)	Computed by EGEM
Volume of runoff (mm)	Computed by EGEM
Detachment rate ($gm^{-2}S^{-1}$)	Computed by EGEM

Key: GPS = global positioning system, SCS = soil conservation service

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 = $2\pi rl_2 - 2\pi rl_1$
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 = $⅓\pi r^2 h_2$ - $⅓\pi r^2 h_1$
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 = $½ \pi R^2 l_2$ - $½ \pi R^2 l_1$
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)

Data analysis

Multiple linear regression analysis and regression graphs were used to obtain the coefficients of determination between measured and EGEM soil losses, as well as to validate the EGEM estimates. In addition, sample means were determined statistically (Statistix 9.0, version 2012).

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RESULTS AND DISCUSSION

Physico-mechanical properties of soils of the study sites

Results of soil physical properties are presented in Table 2. The results indicated that the soils were either sandy clay loam or sandy loam, indicating that the soils were formed under uniform environmental conditions (Oygarden, 2003). The variation in soil loss was perhaps due to differences in drainage areas, channel characteristics and surface obstructions rather than differences in soil types. The exception at Gella site was likely due to its high sand content with possible intermixes or active migration of finer particles (clay and silt) through argilic pedoturbation processes in the soils. This concurs with the report of Yair and Lavee (1985), who mentioned that increased sandiness occurs when selective migration of finer particles in soils happens, such that the coarse particles become progressively coarser. Thus, the soil permeability corresponded well with the soil particle size distributions observed in the sites, especially where Gella had the most relatively permeable soils compared to those of other sites. However, the sandiness (though tightly held by clay aggregates and rock materials) at Gella still contributed to soil loss, than at Lamorde with comparably less soil loss, despite the smaller drainage area sizes of the sites. In addition, the cohesive clay skins, rock outcrops and terraces relatively obstructed soil movement during erosion process at the sites.

Table 2: Physical properties of soils of the study area

Study location	Particle size distribution (%)			Texture	Bulk density	WHC	Site slope	Shape of EG	DA size (ha)
	Sand	Silt	Clay	Class	(Mgm^{-3})	(%)			
Digil	53.61	19.92	26.47	SCL	1.41	28.75	5	U	1.61
Vimtim	59.19	18.05	22.76	SCL	1.38	21.92	15	V	1.63
Muvur	51.88	22.16	25.96	SCL	1.35	26.94	13	U	2.80
Gella	62.41	18.06	19.53	SL	1.34	19.09	15	V	1.20
Lamorde	51.96	24.57	23.47	SCL	1.35	26.59	21	U	1.18
Madanya	50.30	24.29	25.41	SCL	1.33	25.47	10	U	1.51

Key: SCL = sandy clay loam; SL = sandy loam; WHC = water holding capacity;
EG = ephemeral gully; DA = drainage area
Adapted from Tekwa *et al.* (2014)

Estimated rainfall data in the study area

The observed rainfall amount in the study area was 859.80 and 888.70 mm in 2008 and 2009, respectively. There were 64 days with 24-hr rainfalls, out of which 17 days had >20 mm depths in 2008, while there were 66 days, and out of which 14 days also had >20 mm rainfalls in 2009. The period erosivity index (PEI) was 23 and 26% in 2008 and 2009 respectively. In addition, the 2 year 24-hr rainfall events were 11.95 and 40.51 mm in 2008 and 2009 respectively, while the 25 year 24-hr rainfall events were 11.85 and 36.01 mm respectively in 2008 and 2009.

Sensitivity trials of EGEM using relevant erosion variables in the various sites

The results of EGEM prediction as influenced by adapted data input variables such as rainfall amount (runoff), EG length, EG depth, soil bulk density, and erodibility indices are presented in Table 3(a-c). The results in Table 3(a) revealed that the effect of these variables expressed both negative and positive correlations with EGEM estimates of VSL in the various sites. It was observed that both soil bulk density and shear strength were negatively correlated with EGEM predicted erosion (ASL, VSL, and MSL) on the aggregate, while soil erodibility indices, EG lengths, and depths were positively correlated with these soil loss categories. The soil shear strength was the major factor limiting excess erosion compared to soil bulk density, depicting reduction in EGEM predicted erosion as their value increased. On the other hand, soil erodibility, EG depth and length were positively associated with predicted erosion. Soil erodibility exerted larger impact on erosion increase compared to both length and depth of the concentrated flow channels. This result implies that EGEM predicted estimates reduced as these variables increased, while the other variables increased erosion in the study area. The observed high relationship between shear strength and EGEM predicted erosion was perhaps due to the relative concentration of exchangeable bases in Madanya soils, compared to other sites. Nachtergaele *et al.* (2001a) and

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Capra *et al.* (2004) also reported the impact of soil shear strength and bulk density as binding agents that resist erosion forces in soils. In addition, the influence of EG length was strongly associated with EGEM predicted estimates, compared to EG depths. Similar relationship was observed previously with EGEM applications in the Mediterranean areas (Nachtergaele *et al.*, 2001a,b; Capra *et al.*, 2004; Nasri *et al.*, 2008) and in other parts of the World (Zhang *et al.*, 1998).

Results in Table 3(b) showed that there were relationships between the erosion variables and EGEM estimates of VSL in the various sites studied. Results indicated that soil bulk density strongly correlated with the predicted erosion (ASL and VSL) at all sites, except at Gella. The strength of their association ranged within an r^2-value of 0.05 - 0.99, and it was followed in the order: Madanya (0.99) ≥ Vimtim (0.98) ≥ Digil (0.89) ≥ Muvur (0.81) ≥ Lamorde (0.79) > Gella (0.05). The effect of adapted erosivity limit (>20 mm) expressed weak correlation with VSL in the sites, except at Lamorde and Madanya with higher r^2-values of 0.71 and 0.91, respectively.

Table 3(a-c): Sensitivity trials between EGEM predictions and some erosion predictor variables:

a). Relationship (linear regression) between some erosion predictors and EGEM estimates of ASL, VSL, and MSL across the study area

Predictor variable	Coefficient of determination (R^2-value)		
	ASL	VSL	MSL
Bulk density (Mg/m^{-3})	-366.35	-1080.25	-1254.68
Soil erodibility index	121.38	179.55	216.47
Soil shear strength (Nm^{-2})	-778.65	-2725.45	-3310.08
EG length (m)	0.500	0.29	0.39
EG depth (cm)	8.57	8.30	10.70

b). Association between some erosion predictors and EGEM estimates of VSL in the various sites

Study location	Bulk density	Runoff volume	EG length	EG depth
	Coefficient of determination (R^2-value)			
Digil	0.89	0.16	0.38	0.15
Vimtim	0.98	0.41	0.66	0.07
Muvur	0.81	0.52	0.89	0.99
Gella	0.05	0.05	0.73	0.45
Lamorde	0.79	0.71	0.64	0.04
Madanya	0.99	0.91	0.95	0.13

c). Association between EG length and estimates of EGEM and measured erosion (ASL) in the various sites

ASL (m^2)	Digil	Vimtim	Muvur	Gella	Lamorde	Madanya
Measured	0.11	0.20	0.96	0.76	0.00	0.95
EGEM	0.98	0.46	0.98	0.81	0.92	1.00

On the other hand, adapted EG length expressed a generally high correlation with the EGEM predicted VSL estimates in the sites, except at Digil with the least r^2-value of 0.38. The influence of EG depth on EGEM adaptation was generally poor, except at Muvur with a high r^2-value of 0.99. It was observed that EG length was the major determinant of erosion (VSL), followed by soil bulk density, as was similarly reported by Nachtergaele *et al.* (2001a,b).
The results in Table 3(c) further presented the relationships between ASL values and EG length sensitivity tests, which portrayed a poor correlation between the actual erosion and EG length at Lamorde (r^2 = 0.00), Digil (r^2 = 0.11), and Vimtim (r^2 = 0.20), while it strongly correlated with length at Muvur (r^2 = 0.96), Madanya (r^2 = 0.95), and Gella (r^2 = 0.76). On the other hand, the EGEM predicted ASL were positively correlated with length at all sites, except Vimtim that had weaker correlation (r^2 = 0.46) with the EG lengths.

In this study, strong relationships were however, observed between EG length and EGEM predicted ASL, than in terms of actual erosion. Similar results have also been reported from other related works, which found a spurious relationship with estimated erosion (Nachtergaele *et al.*, 2001a & b; Capra *et al.*, 2004). This result however, further attest to the strong influence of EG length on erosion (ASL and VSL) as reported by Nasri *et al.* (2008).

Estimates of EGEM predicted soil loss using unmodified input variables

The results of initial trial of standard EGEM using initial values of relevant input variables are presented in Table 4.

Table 4: Estimates of measured and initial EGEM predicted area of soil loss (ASL), volume of soil loss (VSL), and mass of soil loss (MSL) in the study area

	Soil loss			
	Measured	EGEM	Measured	EGEM
Study location	2008		2009	
		Area of soil loss (m^2)		
Digil	214.38	383.12	266.06	285.99
Vimtim	325.60	275.20	306.37	249.57
Muvur	597.43	296.78	343.12	349.39
Gella	376.03	91.73	426.78	152.44
Lamorde	168.93	95.78	70.02	160.53
Madanya	217.52	308.92	133.14	203.70
		Volume of soil loss (m^3)		
Digil	161.35	135.21	184.25	132.33
Vimtim	328.61	162.58	278.11	169.19
Muvur	299.06	272.80	311.91	312.97
Gella	115.34	27.57	151.24	45.09
Lamorde	144.84	128.69	179.16	138.25
Madanya	73.42	130.16	90.06	118.85
		Mass of soil loss (kg/ha)		
Digil	227.50	189.97	258.51	187.67
Vimtim	446.33	217.47	344.49	224.25
Muvur	400.19	366.26	397.89	397.30
Gella	154.23	36.04	200.63	58.94
Lamorde	196.20	171.36	228.67	175.14
Madanya	98.78	179.03	114.46	162.10

Adapted from Tekwa *et al.* (2014)

The measured and EGEM erosion were generally comparable across sites, soil loss types, and study seasons. In 2008, the measured erosion ranged from 214.38 - 597.43 m^2, 73.42 - 328.61 m^3, and 98.78 - 446.33 kg/ha in respect of ASL, VSL, and MSL, while it respectively ranged from 91.73 - 383.12 m^2, 27.57 - 272.80 m^3, and 36.04 - 366.26 kg/ha in terms of EGEM predicted soil loss. Also, in the preceding season, the measured erosion ranged from 70.02 - 426.78 m^2, 90.06 - 311.91 m^3, and 114.46 - 397.89 kg/ha in respect of ASL, VSL, and MSL, while it was from 152.44 - 285.99 m^2, 45.09 - 312.97 m^3, and 58.94 - 397.30 kg/ha respectively in terms of EGEM predicted ASL, VSL, and MSL in 2009. The measured and EGEM soil loss varied among sites and between seasons. EGEM predicted area of soil loss was higher at Digil in 2008, and lower at Gella in both years. Both EGEM and measured erosion exhibited repeated patterns, especially in volume and mass of soil loss across sites, regardless of season.

EGEM predicted erosion using adjusted EG depths and lengths in the study sites

The results of percentage influence of EG depth adaptation trials on changes in soil loss are presented in Table 6. In 2008, the results indicated that adjustments of 2 - 3 cm depths resulted in varying erosion progress in the various sites. For instance, a 2 cm (or 7%) reduction in EG depth, reduced ASL by 24%, and increased VSL and MSL by 44 and 45% respectively at Digil in 2008, compared to the same 2 cm (or 7%) decrease in depth, which reduced ASL by 16%, and increased both VSL and MSL by 190 and 197% respectively, at Madanya in the same year. Similar observations were drawn for the various sites, especially at Gella in 2009, where a 3 cm (or 13%) decrease in depth reduced the ASL, VSL, and MSL by 71, 17 and 18% respectively, compared to a similar 3 cm (or 9%) decrease in depth at Digil that reduced ASL by 125%, and increased VSL and MSL by 16 and 15% respectively. In this study, decrease in EG depths at Muvur and Lamorde increased the ASL by 16 and 8% respectively in 2009. It was observed that decreases in EG depths generally reduced ASL at the various sites, except at Muvur and Lamorde in 2009, and it increased VSL and MSL at Digil, Muvur, and Madanya in 2008, and at Vimtim, Muvur, and Madanya in 2009. The associated erosion losses in the various sites ranged from 16 - 64, 1 - 124 and 31 - 197% in terms of ASL, VSL, and MSL in 2008, while it was respectively from 8 - 125, 16 - 109 and 0.2 - 118% in 2009. It was observed that erosion magnitude was perhaps dependant on causative rainfall or other soil properties, rather than the effect of the depth adjustments. This was perhaps because of the fact that a uniform percentage adjustment could correspond with different erosion behaviors, where soil loss may still be under or over predicted in the various sites. Future simulation works may however, consider improving $EGEM_{std}$ using adaptation trials of several other erosion variables, as suggested by Nachtergaele *et al.* (2001b).

On the other hand, the results of adjustments made on EG length using ratios and corresponding erosion progress are also presented in Table 6. The results indicated that EGEM predictions in the various sites were influenced in both years. For instance, only a 4% reduction in EG length reduced ASL by 26%, and increased VSL and MSL by 122 and 127% respectively at Muvur in 2008, compared to a 44% decrease in length at Digil that resulted in 52% decline in ASL, and 19% increase in both VSL and MSL in the same year. In addition, a 19% decline in EG length at Gella yielded the highest decrease in ASL by 68% and the lowest decrease in both VSL and MSL by 2% each in 2008. Similar trends were observed in the various sites, where the largest reduction in length by 43% at Digil, yielded about 48% decrease in ASL, and the smallest increase in VSL and MSL by 7 and 8% respectively in 2009, compared to the smallest adjustment in length by 12%, resulted in a slight reduction in ASL by 10%, and an increase in VSL and MSL by 101 and 109%, respectively at Muvur in the same year. It was also observed that all other sites had their ASL reduced due to the EG length adjustments, while only Muvur and Madanya sites had their VSL and MSL increased in both years, in addition to Digil in 2009. The associated erosion losses in the various sites ranged from 26 - 68, 2 - 122 and 2 - 127% in terms of ASL, VSL, and MSL in 2008, while it was respectively from 8 - 76, 7 - 101 and 8 - 109% in 2009.

Table 5: Sensitivity tests of EG depth and length on EGEM prediction of associated area, volume, and mass of soil loss in the various sites

	Average EG		Adjusted EG		Change in EG		Ratio		Associated soil loss (%)					
	Depth	Length	Depth	Length	Depth	Length	Depth	Length	Area of soil loss		Volume of soil loss		Mass of soil loss	
	(cm)		(cm)		(%)				$EGEM_{AD}$	$EGEM_{AL}$	$EGEM_{AD}$	$EGEM_{AL}$	$EGEM_{AD}$	$EGEM_{AL}$
2008														
Digil	30	100.67	28	56.33	7	44	0.92	0.56	24	52	44	19	45	19
Vimtim	28	128.31	25	78.40	11	39	0.91	0.61	48	63	43	57	42	56
Muvur	36	170.89	33	164.35	8	4	0.93	0.96	24	26	124	122	128	127
Gella	20	89.63	18	72.37	10	19	0.88	0.81	64	68	1	2	95	2
Lamorde	28	73.34	25	59.77	11	19	0.91	0.81	46	55	30	36	31	36
Madanya	30	113.36	28	65.87	7	42	0.92	0.58	16	54	190	62	197	62
2009														
Digil	33	105.65	30	60.34	9	43	0.91	0.57	125	48	16	7	15	8
Vimtim	38	137.32	36	101.94	5	26	0.95	0.74	26	62	16	40	0.2	33
Muvur	41	180.04	38	158.01	7	12	0.93	0.88	16	10	109	101	118	109
Gella	23	96.68	20	77.89	13	19	0.87	0.81	71	76	17	35	18	36
Lamorde	33	80.71	30	68.57	9	15	0.91	0.85	8	8	44	53	43	50
Madanya	36	112.32	33	72.11	8	36	0.92	0.64	35	52	59	17	73	24

Key: $EGEM_{AD}$ = ephemeral gully erosion model prediction of soil loss as influenced by adjusted EG depth
$EGEM_{AL}$ = ephemeral gully erosion model prediction of soil loss as influenced by adjusted EG length

CONCLUSION AND RECOMMENDATION

It suffices to conclude that EGEM was adaptable using the observed erosion variables, which exhibited both increasing (soil erodibility, EG depth and length) and decreasing (soil shear strength and bulk density) effects on the extents of predicted soil loss by EGEM under local conditions of Mubi environment. Both EG length and soil bulk density strongly influenced erosion behavior, in addition to EG depth. Soil loss magnitudes varied with EG channel sizes, and the channels voided more or less in response to slight adjustments in EG lengths or depths at each season. Therefore, any conservation method(s) that could reduce EG depth and length advances are strongly recommended as essential EG erosion control in the study area.

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