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ESTIMATION OF SOIL LOSS BY GULLY EROSION IN MUBI, ADAMAWA STATE, NIGERIA

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ABSTRACT
Six locations in Mubi, Adamawa State (Digil, Muvur, Vimtim Gella, Lamorde and Madanya) affected by gully erosion were surveyed between April, 2003 and November, 2004. Parameters related to soil erosion losses such as slope, topography, vegetation and land use were noted or measured. Photographs of the affected areas were also taken. Soils were sampled and analysed for some physico-chemical properties in the laboratory. Estimates of soil loss by gully erosion were evaluated by measuring the weights and volumes of soil loss. Survey of the gully sites revealed a gentle to steep slopes with undulating topography. Land-use types were of arable farming and livestock production. Gully shapes in the areas studied were either of U or V shaped channels with low to moderate depths at considerable lengths. The soils are loamy in texture with moderate organic matter. The soil erodibility index values averaged between 0.16 and 0.23, while the seasonality of rainfall shows that most of the areas are under markedly seasonal regime (SI = 0.08 – 0.99) with an average rainfall erosivity index of 683. 60 ± 0.05 in year 2003 and 655.25 ± 0.05 in year 2004. The magnitude of soil loss ranged from 159,574.14kg to 725,345.01kg per hectare furrow slice in 2003, and from 101,556kg to 984,400.56 kg per hectare furrow slice in 2004. The Magnitude of soil loss through gully erosion was greater in Digil followed by Muvur then Madanya and Lamorde. While volume of soil lost to erosion was least in Vimtim and Gella. It is therefore recommended that simple agriculturally based gully control measures should be employed to control the menace.

Key words: Gully, Erosivity Index, Erodibility Index, Soil Loss.

INTRODUCTION

Soil erosion perhaps constitutes the most serious land management problem threatening man and his ecosystem. It transforms soils into sediments, which consequently transcends into loss of soil and soil materials, at times causing pollution problems that degenerate into loss of life and valuable properties. The severity of soil erosion depends on climate (rainfall amount and intensity temperature), vegetation, topography and nature of the soils (Ekwue and Tashiwa, 1992). Erosion is a three-phase process consisting of detachment of individual soil particles from the soil mass and their transportation by erosive agents (e.g. wind or water) with subsequent deposition of the eroded sediments into land depressions, as influenced by natural (geologic soil erosion) or human (accelerated soil erosion) activities (Hudson, 1989). With water erosion, the progressive concentration of surface run off starts with sheet erosion (the washing of the surface soil from arable lands) then rill erosion, as the water concentrates into small rivulets in the fields, then gully erosion, which occurs when the eroded channels are larger (Hudson 1989).

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In Nigeria, especially the North Eastern parts (e.g. Adamawa, Gombe and Bauchi states) high rainfall intensities are experienced at the on sets of rainy-seasons when the lands are bare and devoid of vegetation cover to offer protection to the soils, thereby disposing the areas to soil loss notably by water erosion. This singular menace has become a matter of concern to farmers in view of its managerial cost implications. A study by Lal (1976) in the same region (N.E. Nigeria), attributed modern gully formations to excessive land – use beyond soil threshold limits by methods of soil and crop management that are ecologically incompatible. Earlier study on soil loss estimate in Biu, Borno State N.E. Nigeria, reveals that over 1000 tonnes of soil per hectare were lost to gully erosion alone (Ekwue and Aliyu, 1990), while an estimated soil loss by gully erosion of 31,000 tonnes soil per hectare in Sade Town, Bauchi State was reported. (Rattenbury *et al.*, 1988).

Mubi and its environs in Adamawa state is one of the most gully affected areas in the North eastern, Nigeria where large farm lands have been lost to gully erosion. This research was therefore conceived from the need to estimate the magnitude of soil loss by gully erosion from some agricultural fields in Mubi area.

THE STUDY AREA

Mubi area (Mubi–North and South LGA) is located in the North eastern part of Adamawa State, lying between latitudes $9^o\ 26^1$ and $10^o\ 10^1$ N, and between longitude $23^o\ 1^1$ and $13^o\ 44^1$ E (figure 1 and 2). It has a land area of 506.40 square kilometres (km^2) with a population size of 759,045 persons with a density of 160.5 persons per a square kilometre (Nwagboso and Uyanga, 1999). The area has a tropical wet and dry climate. Dry season lasts for a minimum of five months (November to March), while the wet season spans from April to October. Mean annual rainfall usually ranges from 700mm to 1,050mm (Adebayo, 2004). The vegetation of the area is Sudan Savannah, implying a grassland interspersed by short trees mainly, acacia, eucalyptus, (Adebayo 2004). The dominant physical feature in the area is the Mandara Mountain which extends throughout the length of the study area, with mixed assemblages of scattered granite outcrops, that shows plains and dissected surfaces on gentle to steep slopes.

MATERIALS AND METHODS:

A detailed survey to estimate the magnitude of soil conceded to gully erosion annually in six gully affected village sites namely Digil, Muvur, Vimtim, Gella, Lamorde and Madanya of Mubi- area was conducted between April to November 2003, and April to November, 2004. Soil loss parameters such as soil erodibility and rainfall erosivity indexes were computed according to Mitchell and Bubnezer (1993) methods. Slope angles were measured using an Abney level, while observations on general topography, vegetation and land use were noted. Photographs of each representative gully site were taken. Some physico-chemical properties of the soil samples such as particles size, (Bouyocous hydrometer method) bulk density, water holding capacity and organic matter (Walkley-Black 1934 method) were analyzed using standard laboratory methods. The data were analysed statistically using statistic 8.0 version 2004 for ANOVA.

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Estimation of Soil

Total soil loss estimate in each gully was obtained using the geomorphologic technique of Norman (1989). The model requires measurements of length, width and depths of each gully channel at 30m intervals. The values obtained are then subjected to mathematical methods (channel geometry) to calculate the land area loss, volume of soil loss and percentage soil loss for each gully.

Estimates of annual soil loss as well as the magnitudes of soil loss progress between the two years understudy were computed.

Mathematical expressions used for the soil loss estimates are as follows:-

(a) Land area loss $= \frac{1}{2} lhb$ i
$= \frac{1}{2} lha$ ii

where b = land area loss before rains
a = land area loss after rains

(b) Volume of soil loss (VSL_2) = $\frac{1}{2}\pi R^2 lBe$ --------------------------------iii
Volume of soil loss (VSL_2) = $\frac{1}{2}\pi R^2 lAf$ ----------------------------------iv

where Be = Volume of soil loss before rains
Af = Volume of soil loss after rains

(c) Percent soil loss = weight of soil loss (WS*L*) x 100%

RESULTS AND DISCUSSIONS

The results of the survey on land use, vegetation, slope and the gully erosion parameters of the studied areas are presented in Table 1. Land use is mainly arable farming and animal grazing while the vegetation consists basically of few grasses, shrubs and trees. The gully are either U or V-shaped with slopes ranging between gentle (0-4%) to steep slope (20-22%). Plates 1 to 6 show the representative gully sites in each studied area.

The dominant soil textural class for all the locations varied from sandy loam at Muvur and Gella, sandy clay loam at Digil Vimtim and Madanya to silty loam at Lamorde (Table 2). The soil texture at Gella changed from sandy loam in the year 2003 to loamy sand in 2004. This change in texture could be as a result of sand and loam skins illuviating or eluviating within the soil profiles or partly due to impeded drainage that resulted in the modification of the surface soil in 2004 (Albert *et al.,* 1980).

The soil bulk density for both disturbed and undisturbed soils of the areas studied averaged 1.264g/cm^3 in 2003 and 2004 as well. This indicates a low to high compaction of the soils, implying the presence of sand concretions that often curtail gully incision at depth of their occurrence (Ekwue and Tashiwa 1992). This phenomenon was prominent in Gella and Vimtim as indicted by their V shaped gullies. This observation agrees with the reports of Nwaka *et al.* (1999) that high bulk density values of 1.7g/cm^3 in sandy soils and 1.45 to 1.65g/cm^3 in clay soils are

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strongly compacted and could even prevent plant growth, hence providing strong resistance to splash detachments of soil aggregates as obtained in this study (Ekwue and Tashiwa 1992).

The water holding capacity of all the soils in the studied area was medium averaging 26.37% for both 2003 and 2004. Soil organic matter ranged from low to medium 0.69 to 1.48% with grand mean of 1.16% in the year 2003 while it increased in 2004 ranging from 0.79 to 1.65% with a grand mean of 1.29%. These values were much lower than 1.23 to 2.46% organic matter reported by Ekwue and Tashiwa (1992) for erosion sites in Mubi Local Government Area. The low values obtained in this study could probably be due to sparse vegetation, overgrazing and land use as influenced by human activity.

The average rainfall Erosivity Index (REI) for both years understudy averaged 680 + 0.05. These values are in agreement with those reported for Hong LGA (750 +0.05) (Ekwue and Tashiwa 1992).

The Soil Erodibility Index (SEI) values of 0.16 – 0.23 for the study area are within the range of 0.12 – 0.44 reported by Ekwue and Tashiwa (1992) for the same area. The values also suitably compare with 0.02- 0.27 reported by Ekwue and Aliyu (1990) for Biu LGA which is in the same ecological zone with Mubi.

The lowest SEI of 0.16 (Vimtim) and highest SEI of 0.23 (Madanya) obtained in this study correspond with where the soil texture is sandy clay loam in nature. This conforms with the report of Evans (1980) and Wischmeier et al (1971) that sandy clay loam textual class is most susceptible to erosion.

The net gully incision depth ranged from 0.65 – 0.89 in 2003 and 0.60 – 0.90m in 2004. This indicates that gully incision rates were consistent every year as a result of the similarity in amounts of rain recorded in both years under study.

The highest gully incision depth (Lamorde) correlated very well with its soil textural class of sandy loam, that is, the erodibility status of the location, while Digil with the lowest gully incision depth could be as a result of its clay nature and coarse sand texture.

The average area of soil loss estimates ranged between 253.02m^2 (Vimtim) and 673.34m^2 (Lamorde) in 2003, while 2004 estimates were slightly higher ranging between 283.00m^2 (Gella) and 688.31m^2 (Lamorde), (Table 3). The variation in soil loss between the years could be due to the organic matter status, of the soils, channel loads and discharges, soil type and probably vegetation cover and land use practices (Hudson 1989). The results reported above also agree with the report of Kaihura et al (1999), that surface soil stoniness, soil consistency and texture greatly determine the gravity of erosion in an area.

The average volume of soil loss estimates in 2003 ranged between 805.93m^3 (Vimtim) to 4133.02m^3 at (Muvur) while the 2004 soil volume conceded to erosion is 520.80m^3 (Gella) and 5609.12m^3 (Muvur). Muvur which recorded the highest volume of soil loss has the wildest gully channel (probably due to high erodibility

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nature of the soils (sandy loam) sparse vegetation and excessive grazing while Gella with the lowest volume of soil loss has the narrowest gully. This result compare favourably with soil loss estimate ranges of 3,024 to 21,615m^3 reported by Ekwue and Tashiwa (1992).

The average weight of soil loss for the year 2003 ranged from 159,574.14kg at Vimtim with narrow gully and 725,345.01 kg at Muvur with widest gully while the 2004 weight of soil loss ranged from 101,556.0kg at Gella to 98,400.86 kg at Muvur. These results are similar to those reported by Rathenbuny et al (1988) of 31,000kg of soil loss from Sade town in Bauchi State.

This variation in weights of soil loss could be due to dissimilar gully widths which can still be related to other gully parameters such as length and incision depth, soil texture and erodilbility levels. However, these results are much higher than those reported by Ekwue and Aliyu (1990) of about 1000 tonnes/ha for soils of Biu L.G.A in Borno State.

CONCLUSION AND RECOMMENDATIONS

It is imperative to mention that gully erosion growth in Mubi area is as a result of combined influence of sparse vegetation, high rainfall (amounts and intensity at the onsets of rainy seasons), soils susceptibility and erodibility, excessive grazing and arable land use beyond tolerable limits. The large soil losses observed in this study seem to correspond closely with gully channel size and shapes, other than the mere impacts of vegetation covers, slopes and even the rainfall amounts during the period.

Suitably compatible conservation measures for the various areas studied are recommended as follows; for Digil and Vimtim because of the similarities of the level of erosion in these areas, gullies can be curtailed by the use of cover cropping systems, crop rotation, reduced grazing and the use of mechanical application of catchment barriers across gullies in retarding channel carrying capacity and or/discharges. Murvur and Lamorde with similar soils and extent of erosion can have controlled grazing, conservation farming of vegetative barriers against run off especially around fresh gully leach-cats as measures of combating gully erosion. Gella with its unique erosion rates and or soils can have vegetative barriers sand bags across the narrow gullies diversion terraces and strip farming method as conservation measures. While the soils of Madanya can be conserved from gully erosion by the construction of check-dams, vegetative catchment barriers and grass water ways across the gullies.

On the whole, this study, has provided the baseline information required on soil loss estimates by gully erosion in Mubi, Adamawa state. It has also brought awareness on erosion problems in the studied area and has proffered measures of curtailing erosion progress in due course. It is expected that, having addressed the factors that expedites gully erosion progress in Mubi-area, relevant agencies will utilize these information in managing this menace in order to maximize agricultural productions and have sustainable environment.

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Table 1: Physico-Chemical Characteristics of Soils of the Study Area

Characteristics	Digil	Muvur	Vimtim	Gella	Lamorde	Madanya
pH 1:2.5 H_2O	5.31	6.15	5.45	5.38	4.65	6.26
pH 1:2.5 Kcl	5.60	6.27	5.72	5.76	4.69	6.06
E.C. (ds/m)	0.05	0.08	0.07	0.03	0.04	0.03
Organic Matter (%)	0.77	1.92	1.08	0.82	0.34	0.29
Total N (%)	0.02	0.21	0.15	0.15	0.17	0.16
Available P (cmol kg^{-1})	17.68	20.83	14.33	22.65	25.88	20.16
Exch. K (cmol kg^{-1})	4.58	3.47	4.23	1.36	2.03	3.20
Ca (cmol kg^{-1})	8.17	9.54	7.55	14.82	9.03	9.76
Mg (cmol kg^{-1})	3.09	12.98	6.32	4.24	0.79	8.35
Na (cmol kg^{-1})	0.83	0.94	0.96	0.37	0.98	0.97
T.E.B (cmol kg^{-1})	16.66	26.89	19.04	21.46	12.82	22.27
C.E.C (cmol kg^{-1})	4.18	6.86	5.72	5.24	3.18	5.53
W.H.C (%)	25.34	27.73	25.51	23.16	27.44	25.14
Bulk Density(g/cm^3)	1.33	1.12	1.31	1.10	1.10	1.23
Sand %	51.93	63.85	67.63	78.67	66.74	58.73
Silt (%)	19.54	15.21	12.84	5.83	16.21	22.24
Clay (%)	28.57	15.21	19.35	15.12	17.56	19.37
Soil Texture	SCL	SL	SL	LS	SCL	SCL

Key: - EC Electrical conductivity
TEB Total Exchangeable bases
CEC Cation Exchange capacity
WHC Water holding capacity
SCL Sandy Clay Loam
SL Sandy Loam
LS Loamy Sand

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Table 2: Present Land-Use, Vegetation, Slope and Gully Erosion Parameters

Location	Present Land use	Vegetation	Shape of Gully	Slope Range (%)	Initial Gully Lengths (m)				Average Gully Width (m)				Gully Incision Depth (m)				Gully Head Length from arbitrary origin (m)			
					2003		2004		2003		2004		2003		2004		2003		2004	
					Apr	Nov	Apr	Nov	Apr	Nov	Apr	Nov	Apr	Nov	Apr	Nov	Apr	Nov	Apr	Nov
Digil	Arable farming/ grazing	Few grasses and Tress	U	0-1 (gentle slopping)	110	116	116	122	9.57	11.23	11.23	12.10	1.75	2.40	2.30	2.90	3.0	7.0	7.0	10.0
Muvur	Arable farming/ grazing	Few grasses and Tress	V	6-8 (Gentle to moderate sloping)	105	115	115	123	17.27	8.97	18.97	21.40	1.75	2.50	2.50	3.20	5.0	8.0	8.0	110
Vimtim	Arable farming/ grazing	Few grasses and Tress	V	7-8 moderate sloping	104	110	110	118	9.17	9.87	9.87	11.07	1.68	2.38	2.40	3.15	4.0	6.0	6.0	8.0
Gella	Arable farming/ grazing	Few grasses and Tress	V	20-22 (steeply sloping)	112	120	120	125	6.63	7.60	7.60	8.10	1.85	2.63	2.60	3.45	2.0	5.0	5.0	7.0
Lamorde	Arable farming/ grazing	Few grasses and Tress	U	7-10 (moderate sloping	130	142	142	155	9.50	11.77	11.77	13.43	2.50	3.39	3.25	4.15	4.0	7.0	7.0	10.0
Madanya	Arable farming/ grazing	Few grasses and Tress	U	0-4 (gentle sloping)	115	121	121	130	10.10	10.80	10.80	12.33	2.46	3.26	3.20	4.00	3.0	6.0	6.0	9.0

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Table 3: Annual soil loss Estimates

Gully Location	Total area of Soil (m^2)		Total volume of Soil loss (m^3)		Weight of Soil lost to Erosion (Kg)		Percentage loss relative to a hectare furrow slice		Average Erodebility Index (AEI)	
	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004
Digil	490.90	373.52	1858.95	1347.98	404321.63	293185.65	18.59	13.48	0.25	0.25
Muvur	565.70	856.45	4133.02	5609.12	725345.01	984400.56	41.33	56.09	0.10	0.10
Vintim	254.02	362.56	805.93	1521.48	159574.14	296688.60	8.06	15.21	0.25	0.25
Gella	357.44	238.00	814.43	520.80	161257.14	101556.00	8.14	5.21	0.10	0.20
Lamurde	673.34	688.31	3195,77	3360.92	589619.57	620089.74	31,96	33,61	0.42	0.42
Madanya	335.80	518.10	986.57	2305.20	211619.27	491007.60	9.87	23.05	0.25	0.25
Mean	446.20	461.82	1965.78	2444.25	37528.46	464488.03	19.66	24.44	0.23	0.25