Int. J. Forest, Soil and Erosion, 2012 2 (4): 192-194
ISSN 2251-6387 [PRINT] 2251-824X [Online]

Research Paper

Quantification and Nutrient Levels of Eroded Soil of Farmlands in Northern Ghana

F. K. Abagale *, J. Coffie and E. Nyadzi
Department of Agricultural Mechanisation and Irrigation Technology, Faculty of Agriculture University for Development Studies, Tamale, Ghana. *Corresponding Author

Received: 2012-05-15 **Accepted: 2012-06-26**

Abstract: The research was conducted as a case study in Dindo community of the Tolon/Kumbungu District in Northern Ghana during the 2010 rainy season. The study determined the volume of soil eroded and the nutrient levels of the eroded and non-eroded soils in both vegetated and non–vegetated areas of the farmlands. Catch pits of dimensions 0.60 m × 0.60 m × 0.18 m were constructed at the top and bottom of farmlands across runoff paths in the farmers' field. Results on volume of soil eroded per rainfall indicated that erosion risk was high in non-vegetated fields. Nitrogen (N), phosphorus (P), potassium (K), organic carbon (OC), pH and organic matter (OM) content in the eroded and non-eroded areas showed significant difference in the content of NPK, OC, pH and OM content in the soil. Soil nutrients level of non-eroded sites was higher than eroded sites. The erosion and soil nutrient loss rates were found to increase with amount of rainfall over a period of time and the observed rainfall intensity.

Keywords: Rainfall, Erosion, Soil, Nutrient, Farmlands.

Introduction

Soil forms an important part of the terrestrial ecosystem and supports the entire human, plant and animal population as it provides the needs of the various inhabitants of the ecosystem ranging from nutrients for plants or food for humans and animals to disposal sites of waste.

Soil erosion is the process of weathering and transport of solids (sediment, soil, rock and other particles) in the natural environment or their source and their deposition elsewhere. It usually occurs due to transport by wind, water, or ice; by down-slope creep of soil and other material under the force of gravity, or by living organisms, such as burrowing animals in the case of bio-erosion (Montgomery, 2008).

Vast tracts of fertile land have been irreversibly converted into infertile pieces of land resulting from the effects of accelerated soil erosion. Soil erosion may be a slow process that continues relatively unnoticed, or it may occur at an alarming rate causing serious loss of topsoil. The loss of soil from farmland may be reflected in reduced crop production potential, lower surface water quality and damaged drainage networks (Wall, 2003).

According to Lal (1995) food production has to be increased substantially to avoid mass starvation in many parts of the world. Although the perpetual food deficit in Africa cannot be entirely attributed to erosion and erosion induced soil degradation and the resulting decline in crop productivity, there is disturbing degree of correspondence between the areas affected by severe soil erosion and those prone to gross food deficit. Africa faces the greatest challenge of breaking the vicious cycle of erosion-induced soil degradation and the resulting decline in crop productivity. Intensification of agriculture is necessary to increase food production, although this also increases the risk of erosion and its consequences.

The study determined the volume and nutrient level of soil eroded per rainfall event of farmlands in the Tolon/Kumbungu District of Northern Ghana.

Materials and Methods

Study Site

The study was undertaken in the Dindo community of the Tolon/Kumbungu District of the Northern Region of Ghana. The study field is located on latitude $09^{0}41^{1}394^{11}$N and longitude $00^{0}991^{1}88^{11}$W and at an elevation of 175 m.

The study area has a unimodal rainfall pattern which begins from April/May to September/October. The mean annual rainfall is 1,043 mm. Temperature generally fluctuates between 15 °C and 42 °C with mean annual temperature of 28.3 °C. The mean annual daily relative humidity is 54 % (SARI, 2002).

The vegetation is mainly woody Guinea Savannah. The common grasses include *Panicum maximum* (Guinea grass) and *Andropogon gayanus* (Gamba grass) whilst the trees include *Azadiracta indica* (Neem), *Parkia biglobosa* (Dawadawa) and *Vitellaria paradoxa* (Shea tree) (MoFA, 2002).

The people are mainly small livestock farmers keeping cattle, sheep, goats, guinea fowls, etc and cultivating crops such as maize (*Zea mays*), sorghum (*Sorghum bicolor*), groundnut (*Arachis hypogaea*), rice *(Oryza glaberrima)*, yam *(Dioscorea spp)*, tomato (*Solanum lycopersicum*), okro *(Abelmoschus esculentus)*, cowpea (*Vigna unguiculata*) and soybeans *(Glycine max)* (Stephen, 2003).

Materials and Data Collection

Catch pits of dimensions 0.60 m × 0.60 m × 0.18 m were constructed with concrete along runoff paths to collect eroded soil in both vegetated and non-vegetated farmlands. Four (4) catch pits, two (2) per location of vegetated and non-vegetated farmlands were used. Soil samples were collected from catch pits of eroded and non-eroded farmlands after every rainfall event. Samples were collected using the diagonal sampling method across the field to reduce homogeneity whilst ensuring true field representation.

Methods

Soil pH (pHw)

0.125 M $CaCl_2$ was added to 10 g of soil sample. De-ionized water was added and stirred and the sample allowed to stand for 30 minutes. The pH was then determined using a calibrated pH meter.

Available Phosphorus

Available phosphorus was determined according to the method by Bray and Kurtz (1945).

Potassium

The potassium level of the soil samples was determined using the procedure described by Bashour and Sayegh (2007) for soils in arid and semi-arid regions.

Organic Carbon

Organic carbon and organic matter were determined using Walkley Black method (Walkley and Black, 1934).

Available Nitrogen Content

One gram of air dried soil was measured into a digestion tube and 2.5 ml digestion mixture was added, three successive adequats of 1 ml hydrogen peroxide was added and heated at 200 °C for 1 hour. The temperature was continually raised until the mixture becomes transparent in about 2 hours. The tubes were removed and allowed to cool after which 10 ml water was added. The mixture was distilled after which 20 ml of boric acid indicator solution was added to 250 ml water; 20 ml of 40 NaOH was added to the digestion tube and distilled for about 7 minutes until 75 ml of distilled water was obtained. It was then titrated with 0.01 M HCl until colour changed from green to pink. Equation 1 was used in the determination of available nitrogen content;

$$\% \text{ Nitrogen} = \frac{(a - b) \times (14 \times M \times V)}{S} \ldots\ldots \text{Eqn (1)}$$

Where;

a = Titre value of sample
b = Titre value of blank
M = Molarity of HCl
V = Total volume of digest
S = Weight of sample

Results and Discussions

Volume of Soil Eroded in Non–Vegetated Area

Results of the study indicated that amount of soil collected in catch pits after rainfall of 11.0 mm, no measurable soil was collected or trapped. This is as a result of the intermittent nature of the rain event which spread over a long period of time and thus unable to generate runoff which is the main driving force for soil particle detachment and entrainment by water. The period between the two (2) rainfall events was 12 days which indicates that the soil needs to be saturated before runoff can occur.

According to Morgan (1995), runoff depends on antecedent moisture condition of the soil. Thus, runoff is generated easily when there is enough storage in the unsaturated and saturated zones respectively. Morgan (1995) indicated that rainfall which reaches the ground may be stored in small depressions or hollows on the surface or it may infiltrate the soil, contributing to soil moisture storage or by deep percolation to the groundwater. When the soil is unable to take in more water, the excess moves laterally downslope within the soil as subsurface or interflow or it contributes to runoff on the surface resulting in erosion by overland flow.

A period of 9 days was observed before a rainfall of 8.6 mm was recorded in the study site. This 8.6 mm rainfall was intense as it occurred over a very short period of time. This high intensity generated runoff which eroded 3.0×10^{-4} m^3 and 1.8×10^{-3} m^3 of soil at the upslope and down slope sites respectively. Rainfall recorded 5 days after the 8.6 mm rain was 46.1 mm and this rainfall event was associated with high intensity and thus detached the soil particles and transported them downslope. Soil volumes of 4.8×10^{-3} m^3 and 9.7×10^{-3} m^3 were collected in the catch pits located upslope and downslope respectively in the study field. The detachment of these high quantities of soil particles can also be attributed to the saturation of the soils as a result of the previous rainfall events.

The difference in volumes between the up and downslopes of the study fields indicates the effect of the erosive power or the energy contained in the rain drop and the flowing water downslope. Table 1 presents the volume of soil eroded from the non-vegetated area of the study site. The effect of lack of vegetative cover is therefore evident in the results tabulated (Table 1). This is because the vegetative cover has the potential of breaking the energy pathway of a raindrop and thus reducing the direct effect on a soil pedon.

Table 1: Volume of Soil Eroded in the Non-vegetated Area per Rainfall

Date	Rainfall Amount (mm)	Volume of Soil Eroded in Non-vegetated Area (m^3) Upslope	Downslope
06/5/10	1.40	-	-
19/5/10	11.0	-	-
29/5/10	8.60	3.0×10^{-4}	1.8×10^{-3}
03/6/10	46.1	4.8×10^{-3}	9.7×10^{-3}

Volume of Soil Eroded in Vegetated Area

The effectiveness of vegetation cover in the control or reduction in the level of soil erosion was determined using the site with vegetative cover. As presented in Table 2 at a rainfall event of 1.4 mm, 11.0 mm and 8.6 mm experienced during the study period, there was no measurable quantity of soil trapped by the catch pit located at both the up and downslope areas in the experimental plots.

The intensity of the vegetation cover was substantially high and thus intercepted the effect of the energy of the rain drops on the soil surface. The direct impact of the rain on the soil surface is therefore reduced tremendously and thus reduces the level of soil particle dispersal and entrainment from the soil surface. According to Lal (1995), vegetation cover close to ground level breaks the raindrop impact, traps transported soil particles and dissipates the energy of raindrop more effectively than tall canopies thereby favouring the prevention of upland erosion caused by splash and overland flow. Soil erosion is decreased with an increased vegetation cover. The above ground component of the vegetation such as leaves and stems, absorbs some of the energy of the falling raindrops, running water and wind such that less of the rain drop energy is directed at the soil, whilst the below ground component, comprising the root system, contribute to mechanical strength of the soil (Morgan, 1995). Erosion in vegetated fields is a natural process and takes a long time to be noticed unless accelerated by human practices that encourage the removal of vegetation. This is the cause of the immeasurable or unquantifiable volume of soil in the catch pits in the vegetated part of the area. Rainfall amount recorded as 46.1 mm was able to detach and transport only very fine soil particles tightly attached to the surface of the soil catch pits. The recorded volume of soil was 3.0×10^{-4} m^3 and 7.0×10^{-3} m^3 for upslope and downslope experimental sites respectively. Management of soil cover in the form of ensuring luxuriant crop growth is therefore very important in reducing soil erosion in agricultural fields as was observed from the results of the experimental sites.

Table 2: Volume of Soil Eroded in Vegetated Area per Rainfall

Date	Rainfall Amount (mm)	Volume of Soil Eroded in Vegetated Area (m^3) Upslope	Downslope
6/5/10	1.4	-	-
19/5/10	11.0	-	-
29/5/10	8.6	-	-
3/6/10	46.1	3.0×10^{-4}	7.0×10^{-3}

Soil pH of Eroded and Non-Eroded Soils

Soil pH is known to measure the acidity or alkalinity of a given soil sample. It is determined by the amount of lime (calcium) contained in the soil. Low pH soil (< 6.0) results in an increase in aluminum which is toxic to plants. Results of the study indicated that soils eroded were losing their pH from nearly neutral or neutral to strongly acidic with pH values from 6.10- 6.15 to 5.41 - 5.49 as was observed in non-eroded and eroded experimental sites respectively. This therefore has an effect on the growth and performance of crops in the farmlands as crops which cannot tolerate acidic soils will not produce the required results in terms of yield. It may also increase the cost of production when lime is applied to correct the deficiency.

Available Nitrogen in Eroded and Non-eroded Soils

Nitrogen content in the experimental sites was within the range of 0.073 - 0.077 % and 0.094 – 0.095 % for eroded and non-eroded sites respectively. Considering the broad rating of nitrogen measurement, the levels of N recorded were observed to be very low. This implies, the N levels contained in the soil have been washed away and thus not available for use by crop plants.

Even though very low levels of N was recorded for the two (eroded and non-eroded) sites, the deficiency in the eroded area was higher than the non-eroded area which indicates that uncontrolled soil erosion by water or rainfall events can drastically wash away available nitrogen in the soil and this may affect the growth and yield of crops.

Phosphorus in Eroded and Non-eroded Soils

It was revealed that phosphorus is acutely deficient in the non-eroded areas with values ranging from 1.28 - 1.30 mg/kg whilst that of the eroded area was from 1.09 - 1.10 mg/kg indicating deficiency. The low phosphorus content in the eroded soil showed that phosphorus is being substituted by aluminium which may go a long way to affect crop production. The low phosphorus content which was present in the eroded area revealed that, soils in that area were weathered more than that of non-eroded area. It is generally known that calcium phosphate decreases while iron phosphate increases with weathering. The results confirmed that both soils were deficient in phosphorus but its availability in the non-eroded area exceeded that of the eroded site which indicates that soil erosion causes serious effect on plant growth and development.

Organic Carbon in Eroded and Non-eroded Soils

Soils under non-eroded and eroded areas were within desirable organic carbon range required for tropical crops production. According to Young (1976), organic carbon range desirable for tropical crop production is between 0.6 – 1.2 %.

Non-eroded experimental sites of the land showed a high OC content of 1.09 – 1.10 % compared to eroded land area which recorded values ranging from 0.85 – 0.89 %. Decreased OC content in soils is a result of continual removal of plant materials for human and animal consumption with relatively little replenishment to the soil. The amount of OC recorded for the two sites therefore is appreciable and high enough to support crop growth. The removal of vegetative cover should therefore be discourage as this has the potential of maintaining the OC at the required range and also adding crop nutrients.

Organic matter in Eroded and Non-eroded Soils

The organic matter content was found to be between 1.50 - 1.53 % in the eroded area whiles that of the non-eroded area was in the range of 1.88 - 1.90 %. Results showed clearly that OM content in the eroded soil was lower and of which can be attributed to erosion washing away the top and high nutrient concentrated portion of the soil which contains high level of organic matter. The low level of organic matter can adversely affect plant growth in the area. According to Woomer and Ingram (1990), the decline of soil OM content to newer, lower equilibrium is attributed to erosion which constitutes a non – renewable removal of soils. Senayah *et al*. (1998) reported that soils in northern Ghana are generally deficient in organic matter. To improve on the productivity of the soils in this region requires the integration of various management practices such as erosion prevention, application of organic matter and inorganic fertilizer as well as integration of legumes into the cropping system.

Table 3 presents the laboratory results of the chemical properties of the soils understudy.

Table 3: Chemical Properties of Eroded and Non-eroded Soils

Label	pH (w)	% N	P (mg/kg)	Exch. K (mg/kg)	% OC	% OM
E_1	5.49	0.075	1.29	70.40	0.87	1.50
E_2	5.41	0.073	1.28	71.34	0.85	1.47
E_3	5.41	0.077	1.30	70.20	0.89	1.53
V_1	6.15	0.094	3.24	79.20	1.09	1.88
V_2	6.10	0.095	3.27	82.00	1.10	1.90
V_3	6.13	0.094	3.26	80.80	1.09	1.88

E_1, E_2, E_3 =soil samples taken from the eroded soil, V_1, V_2, V_3 = soil samples taken from non-eroded area.
N= nitrogen P= phosphorus, Exch. K= exchangeable potassium, OC= organic carbon OM= organic matter

Conclusions

The results of the study indicated that soil erosion poses problems on farmlands with little or no vegetative cover protection compared with soils with vegetative cover. Volumes of soil collected in catch pits in vegetated areas were very low and very fine soil particles tightly bonded to the floor of the catch pits whiles substantial quantities or volumes of soil was collected from the non–vegetated study areas and catch pits. Levels of soil nutrients such as nitrogen, phosphorus, potassium and OC decreased as a result of soil erosion. This has the potential of resulting in very deficient soil nutrient levels and thus may retard the growth and yield of the crops. Soil pH changed from the neutral to acidic range due to the washing away of the basic ions contained in the soil.

It is recommended that erosion control measures be put in place to reduce the rate of soil erosion and thus increase the nutrient level and/or status of the soils in the area for good growth and high crop yields.

References

Bashour I I and Sayegh A H (2007). Method of Analysis of Soils for Soils of Arid and Semi-Arid Regions. FAO 2007.

Bray R H and Kurtz L T (1945). Determination of total, organic and available forms of phosphorus in Soils. Soil Sci. 59:39-45.

Lal R (1995). Sustainable Management of Soils in the Humid Tropics. United Nation University Press

MoF A (2002) in W. Stephen (2003) Prospects and Constraints of Forage Production in Tolon/Kumbungu District. B.Sc. Dissertation, University for Development Studies-Tamale. Unpublished.

Montgomery D (2008). Dirt: The Erosion of Civilizations (1st ed.). University of California Press. ISBN 0520258061.

Morgan R P C (1995) Soil erosion and conservation. Second edition, Longman.

SARI (2002) in W. Stephen (2003) Prospects and Constraints of Forage Production in Tolon/Kumbungu District. B.Sc. Dissertation, University for Development Studies-Tamale. Unpublished.

Senayah J K, Adjei – Gyapong T and Asiama R D (1998). Soils of the Busia Agricultural Station, Near Wa in the Upper West Region, Kwadaso – Kumasi.

Stephen W (2003) Prospects and Constraints of Forage Production in Tolon-Kumbungu District. B.Sc. Dissertation, University for Development Studies-Tamale. Unpublished

Walkley A and Black I A (1934). An examination of the Degtjareff method for determining organic carbon in soils: Effect of variations in digestion conditions and of inorganic soil constituents. Soil Sci. 63:251-263.

Wall G (2003). Soil Erosion-Causes and Effects, Ontario Institute of Pedology; ISSN 1198-712X, Queens Printer for Ontario

Woomer P L and Ingram J S I (eds). (1990). The Biology and Fertility of Tropical Soils. Report of the Tropical Soils Biology and Fertility Programme, 1990, Nairobi, Kenya : TSBF

Young A. (1976). Tropical soils and soil survey. Cambridge Univ. Press.