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Soil-Crop Relationship in Gully-Impacted Farmlands along Ata Obio Akpa Watershed, Oruk Anam, Akwa Ibom State, Nigeria

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***Keyword:** Gully, soil, Crop, Farms, Oruk Anam*

Abstract

Gully erosion subjects soils to breakdown of equilibrium, which is detrimental to crop production. This work examined the soil-crop relationship in gully impacted farmlands along Ata Obio Akpa watershed, Oruk Anam, Akwa Ibom State. Twenty four soil samples were collected from identified gully farmlands and control plots at two farms in the community selected through stratified random sampling for physicochemical properties of soils. Soil samples were collected using hand auger at two depths (topsoil 0-15cm and subsoil – 15- 30cm). Two hypotheses which stated that "there is no significant variation in soil properties between gully-impacted and control plots" and that "there is no significant effect of gully soil on crop production". T-test statistic at p< 0.05 revealed that the properties of soil vary between gully-impacted and control plot. The Regression Statistic shows that B.Sat and ECEC contributed more at r>70% and p<0.05 than other variables which contributed low and moderately at p>0.05, with r>60% and r<60% respectively. The *regression model showed the trend of input and output at one unit increase, soil properties increase at different proportions where B.Sat and ECEC had the highest input to crop production. Also, this research discovered that crop production was unstable within the same terrain under gully influence where the upper slope produced differently from the middle slope as well as the valley bottom. From the study, it can be clearly stated that the dynamics of soil properties influenced by gully scenario have determined the farm output with respect to topographic points. Therefore, it is recommended that proper attention be given to this devastated terrain so as to reclaim the value of the agro-ecological community and sustainable enhance crop production efficiency and environmental resource management in the region.*

Introduction

Introduction

Crop production as a primary source of livelihood in developed and developing countries have been threatened by diverse kinds of environmental degradation. Readily discerned environmental degradation processes that affect Akwa ibom and elsewhere is soil erosion. Soil erosion has been recognized as the major cause of land degradation and in past decades, priority of research has been given to address agricultural issues at the pilot scale and thus to rill and inter-rill erosion (Valentin, Poesen and Kun 2005). However, in recent times, gully erosion as an endemic ecological problem is recognized in numerous studies as an area of growing interest among humid and sub humid regions of the world (Casali, Gimenez&Benneh, 2009; Valentin et al, 2005; Apkokodje, Tse&Ekeocha, 2010; Jonathan and Joshua, 2013). Gully development subjects soil to breakdown of equilibrium and stabilizing agent to the detriment of crop producers. Gullies represent extreme manifestation of the complex processes of accelerated soil erosion that renders crop production poor (Udosen, 2008). Gully processes have a three dimensional nature affected by a wide array of factors and processes (Valentin*et al*, 2005). Although it is commonly triggered and accelerated by land use change and /or extreme climatic event, it often results also from a long antecedent history that cannot be over emphasized when attempting to understand spatial erosion patterns. Moreover, many gullies grow initially rapidly to large dimensions (Thomas, Iverson, Burkart and Kramer, 2004), and it makes effective control technically difficult or prohibitively expensive (Valentin et al, 2005).

The effects of gully erosion on agro-environment are usually unpredictable impacts which are more serious and flashy as they include loss of available land and increase of labour costs to crop grower (Govers, Poesen, Goosens and Christensen, 2004). Gully erosion is often the main source of sediments to downstream farms with low lying terrain (Wason, Caotvjeon, Murray, McCulloch and Quade, 2002). The alarming results from one- time de-surfacing experiments that attempt to mock inter -rill erosion by (Govers *et al* 2004) note that gradual erosion has much weaker effect on crop productions than the sudden removal of a significant proportion of the top soil (Govers *et al*, 2004).

Agriculture is facing a lot of challenges even though it is the principal source of food and livelihood in Nigeria. Among these challenges are neglect of the sector from governments, land tenure insecurity and changes in agro-ecology, poverty and inadequate technical know-how of farmers and land degradation as well (Garba and Dalhatu, 2015). Titilola and Jeje (2008) discovered the effects of erosion on agriculture and its increasing impacts on rural development. In the research, it was observed that erosion drastically affects physiochemical properties of soils where soils suffered a significant depletion of clay in A-horizon, metallic cations, organic carbon, nitrogen and available phosphorus as well as cations exchange capacity. Abegunde, Adeinka & Oluode (2006) argued that soil erosion limits land utility which adversely affects food supply and food security at national and household level. In Nigeria especially the South Eastern part of Nigeria, some of the gullies have existed for more than 50 years and new ones are springing up daily (Abegunde; Adeyinka; Oluode, 2006 quoted Owens *et al,* 2000). Similar cases have been recorded in Northern and Western Nigeria (Titilola and Jeje, 2008).Crops are particularly reliant on the horizons of the soil which are the most vulnerable to erosion by running water and wind (Danladi and Ray, 2014).From the soil loss, erosion drastically affect the physico-chemical properties of the soil impacted, which suffered a significant depletion of clay in A-horizon, metallic cations, organic carbon, nitrogen and available phosphorus as well as cations exchange capacity (Titilola and Jeje, 2008).

In Akwa Ibom State, the effect of gully erosion on soil is recognized by different scholars (Udosen, 2008; Essien and Essien, 2012). Ata ObioAkpa, the study area is under severe impact of gully development on agricultural productivity. Accounting for the predictors of crop productivity reduction becomes pivotal for agricultural development since the location is an agricultural region and majority of depend on crop production for livelihood. The increasing effect of gully erosion on the soil of Ata ObioAkpa has greater impacts on the socio-dynamics of development of Akwa IbomState and Nigeria since agriculture is an integral part of development. In spite of the gully development in Ata ObioAkpa, farmers still engage in cropping at gully impacted sites along topographic sequential heights and crops grow at varying elevations on the slope. Gully impacted sites shows complete breakdown of soil equilibrium and stabilization potential for effective crop production. Runoff descend on the steep slope provoke channel incision with massive nutrient transportation. Therefore, examining the parameters of the soil impacted by gully, and the outcome of agricultural production is pertinent.

Study Area

OrukAnam Local government Area, AkwaIbom State, Nigeria lies between latitude $4^0$7'N and 5^0 49'E and longitude 7^0 40'E and $7^0$49'E. OrukAnam belongs to the humid tropical zone and the climate is influenced by two marketed seasons viz, the wet and dry seasons. Heavy rainfall spread over eight months of the year. The two air masses influencing these seasons are tropical meantime and tropical contractual air masses. The former gives way to rain season and the later dry season. The study area lies within the subtropical rainforest and mangrove swampy vegetation zone. The entire vegetation has large expanse of land full of oil palm trees and other trees that thrive on the area and are both tall and short trees. The humid nature of the area has characterized the vegetation by abundant flora and fauna of ecological importance and resource-rich composition. The landscape rises gradually and lies about 45 metres above sea level. The area is on the sandy plain of South Eastern Nigeria where sediments come from different drainage canals of Cross and Kwa Iboe River. The physiographic region of Oruk Anam is subject to geomorphic and meteorological factors which give rise to development of ferralsols with completely weathered soil consisting of resistant mineral such as quartz-rich free iron and low mineral. The sands here are sometimes cross-bedded with clays and sand clay occurring in lenses (Udosen, 2008).The soils have deep profiles with little gravel in the subsoil and the dominance of sand particles in the soil materials decreases the clay fraction may have on the physical and chemical properties (Udosen, 2007).

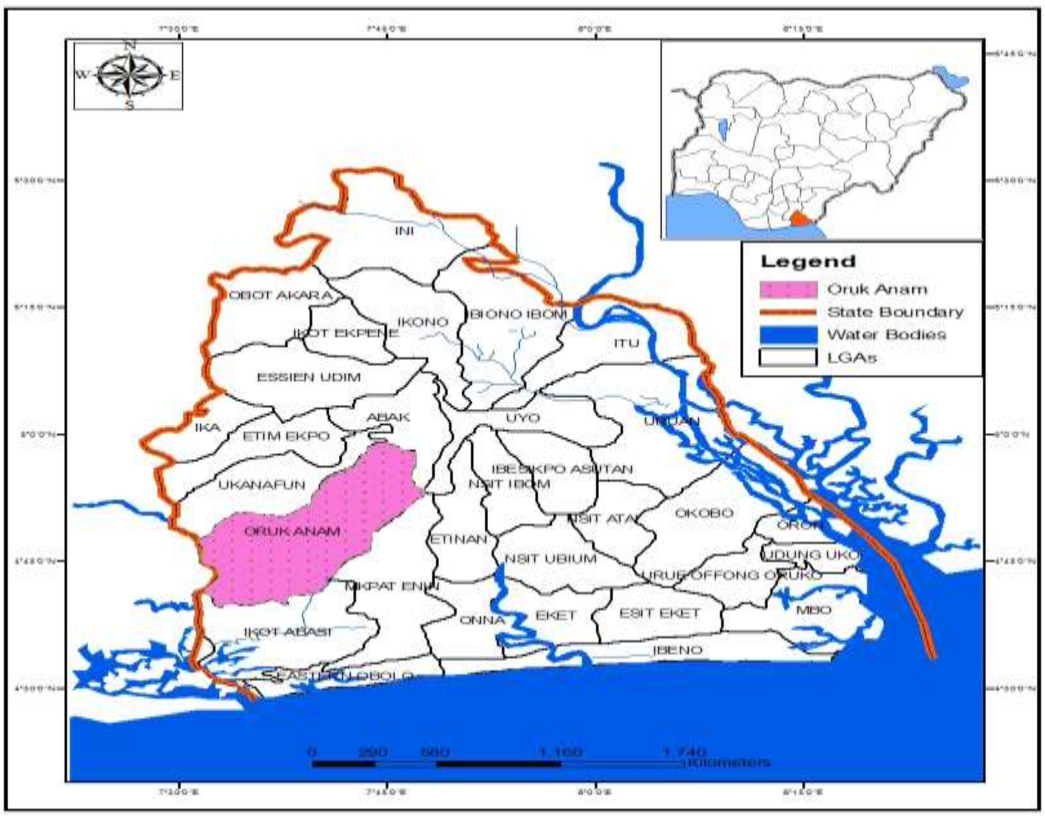

Fig. 1.AkwaIbom showing OrukAnam

Materials and Methods

Field and Laboratory Methods for soil analysis

Soil samples were collected at two mega farms in the community highly impacted by gully scenario and also at control plots by these farms. In each farm, a transect was drawn and divided into crest, middle slope and valley bottom on a sampling interval of 25m with a total elevation of 54m above sea level. A total of twenty four samples were drawn and subjected to laboratory analysis. Soil samples were taken to University of Uyo Soil Lab for laboratory analysis of physicochemical properties of soil. The physical properties of the soil determined are particle size distribution, soil texture and organic matter. Particle size distribution was determined with a boyocuos hydrometer after digesting soil organic matter with hydrogen peroxide and soil dispersion with sodium hexametaphosphate (Okalebo, Gathua&Woomer, 2002). This involved the measurement of the percentage of the mineral separates namely sand, silt and clay. The procedure has two aspects: soil dispersion and fractionation into particle size classes. The soil dispersion followed the methods of stirring soil sample with calgon or sodium hexametaphosphate solution. The determination of sand fraction was by sieving, silt content and clay was determined by sedimentation- hydrometer method (Lyman Brigs, 1982).The soil samples from the sampled gully sites were brought to the laboratory and were air dried and passed through 2mm mesh or sieve. After determining the particle size distribution, the textural classes can be derived from the result based on the proportion of sand to silt and clay which will determine which class it belongs. The property used sedimentation method in the laboratory as described by Lyman Briggs (1982).

Soil pH was determined by the use of pH meter and glass electrode in a soil solution ratio of 1:1.Organic carbon was determined by Walkey Black Digestion Method. Total Nitrogen was determined by the macro- Kjeldahl method as described by digesting in concentrated NH4SO4 containing potassium sulphate and distilling as NH3 gas into boric acid solution trap. Available phosphorus was extracted by sulphuric/ per chloric acid digestion with mixtures taken up in dilute hydrochloric acids using Bray P-1 method (Bray & Kurtz, 1945). Exchangeable cations were determined by displacement of the ions from the soil colloids using 1N NH4OAC (pH7.0). The potassium and sodium content in the extract were determined by Flame-photometer while Calcium and magnesium were determined by EDTA titration (Jackson, 1962). Exchange acidity was determined by the potassium chloride (IN KCl) extraction method. Total Nitrogen was obtained by micro Kjeidal Digestion and distillation method, (Jackson, 1962). Effective Cation

Exchange Capacity (ECEC) was calculated as the sum of all base forming cations plus exchange acidity.

Field and Laboratory Methods for crop production

The major seasonal crop during the period of studies (cassava) was studied and at the sampled locations, 5 tubers were sampled at each topographic unit along the toosequence from the crest to the valley bottom on transect of sampling interval of 25m selected on the same elevation of the soil studies. In every 5m, a tuber was sampled making a total of 5 per slope positions, and in farms A and B, 30 tubers were collected and subjected to studies. Cassava tubers of the same species and varieties were collected and air dried for test. The determination of crop production was carried out using weighing balance to examine in kilograms per meters sampled, (the mass per distance) of the cassava tuber collected at different slope segment to check for variations and correlate with the soil parameters at Obio Akpa farms. The mean of the five crops were computed for at each slope before correlating with the soil properties.

Results and Discussion

Geography of Gully-Impacted Sites

The sampled farmlands had higher elevations at the upper slope and decreases down the slope. This can help in determining the relief and roughness coefficient which is topographic in description and can explain the terrain of the farmlands. The coordinates were not similar but they were close in values showing that the study area had proximate geographic identities.

Table 1 Gully Impacted Sites, Geographical Coordinates and elevation

SAMPLES SITES	POSITION	LATITUDE	LONGITUDE	ELEVATION
FARM A	US	N 0468.421	007^0 48.331’	**40M**
	MS	N 0457.593	007^0 45.531’	**33M**
	LS	N0462.409	007^0 48.358’	**22M**
FARM B	**US**	**NO 4^0 60.515**	**007^0 45.271’**	**41M**
	MS	**N04^0 61.248**	**007 ^{0}46.184’**	**34M**
	LS	**N04^{0}60.420**	**007^0 43.234’**	**26M**

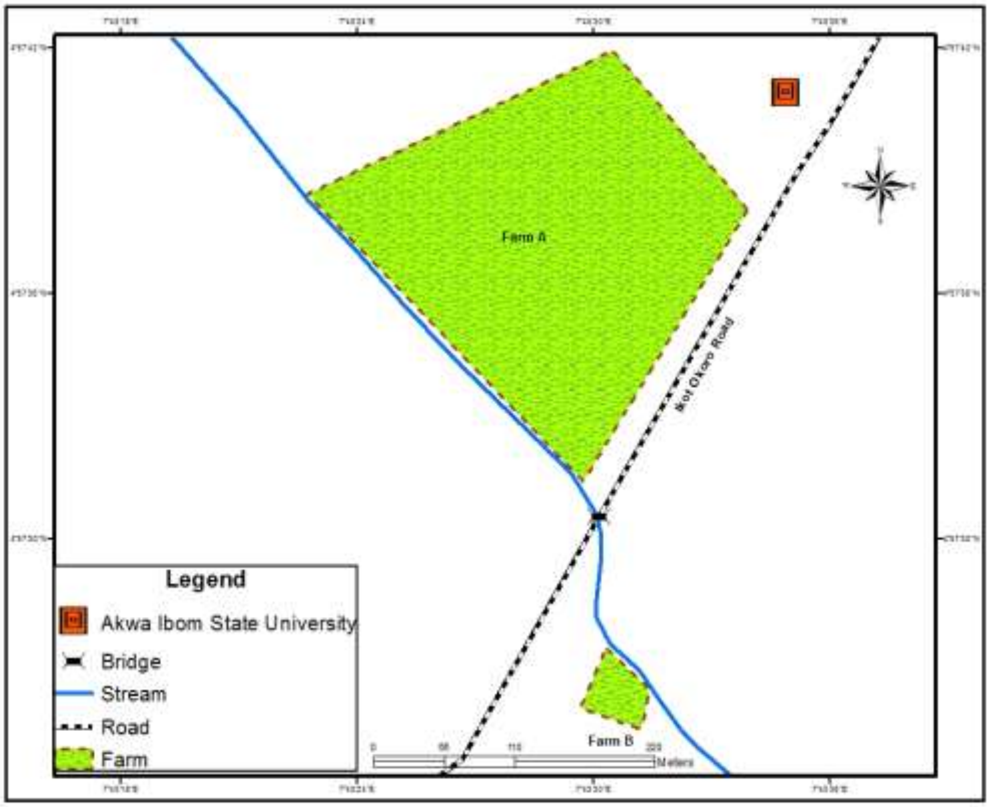

Fig.2 Ata-Obio Akpa Watershed showing Gully-impacted farmlands

Particle size Distribution of soils in Ata Obio Akpa Farms

Sand fraction at Farm A ranged from 84.00% to 90.00% and it was highest at the middle slope and (0.15) lowest at upper slope (15-30). The mean of sand fraction in Farm A is 87.6+0.84% and mean of top soil sand fraction is 88.9+0.74%. In Farm B, and fraction ranged from 86.90% to 88.50% and it was highest at the upper slope (15-30cm) and middle slope (0-15cm) and lowest at lowest slope (15-30cm). The mean of the sand fraction in the entire farm B is 88.1+0.3%. Sand particles exhibited moderate to little variation from topsoil to subsoil in the different gully sites with the coefficient of variation of 0.27 % to 0.7 %. From the result, it shows that sand fraction did not vary significantly between topsoil and subsoil in the gully impacted farmlands in the study area.

The values of clay did not vary significantly across the farmlands in both topsoil and subsoil. Clay ranged from 6.0% to 9.0%. The highest clay content (90.0%) was recorded at the subsoil of the upper slop (15.30cm) in farm A and the lowest was at the topsoil of the middle slope in farm A also. The clay content in the subsoil was highest ranging from (7.0% to 9.0%) and 6.10% to 7.5% at the topsoil being the lowest. The silt content was the least with values ranging from 4.0% to 7.0%. In the topsoil, the values ranged from 4.4% to 7.0%. In the top soil, the values ranged from 4.0% to 5.10% with the mean of 4.4%, with the highest (5.10%) at the lower slope of farm A. silt content increases from top soil to subsoil in farm A and Farm B. in Farm A, the mean value for silt content is 5.2±3.9 and in farm B is 4.43±0.2.

Table 2 Particle size distribution of soils in Ata ObioAkpa farms

PROPERTY	FARM A			FARM B		
	US	MS	LS	US	MS	LS
SAND	86.45±0.7	88.95±0.65	87.4±0.8	88.45±0.11	88.25±0.1	87.65±0.5
SILT	6.02±0.2	4.6±0.3	5.1±0.5	4.1±0.13	4.6±0.2	4.6±0.3
CLAY	7.6±0.3	6.5±0.6	7.5±0.42	7.75±0.1	7.65±0.01	7.75±0.005

Organic Matter Content of the Farmlands in the Study Area

The organic matter content of the soils ranged from 0.54% to 2.38%. For the topsoil, it ranged from 0.85% to 2.38% and ranged from 0.54% to 2.31%. In farm A, organic matter content was highest (2.140%) at the subsoil of the lower slope and lowest (0.85%) at the topsoil of lower slope. In farm B, organic matter content ranged from 0.54% to 2.38% and was highest at the top soil of middle slope with 2.38% and lowest at the subsoil of middle slope with 0.54%. The lowest and highest organic matter content were in farm B. There is significant variation in organic matter content across the gully farmlands. Continuous cultivation affects the content of organic matter.

Table 3 Organic matter content of soils

SLOPE POSITIONS	FARM A	FARM B
UPPER SLOPE	1.67±0.37	2.11±0.28
MIDDLE SLOPE	1.38±0.48	1.46±0.4
LOWER SLOPE	1.50±0.29	1.33±0.35

Chemical properties of soils in the study area

Soil pH and BS% values were consistently slight variable irrespective of the farmland.Soil pH is a very important paramount that influences many physical and chemical properties of soils including the availability of nutrients. Despite the fact that the variability reported for pH is small, minor changes in pH units have significant effects on nutrient availability.The soil chemical parameters were highest in the MS and LS, except for EC, PH which was the highest in the US and TN in MS than LS. The highest content of available P observed in the study areadue to the relatively high organic matter content or high inherent P content of the parent material. This result it in agreement with the results reported by two authors (Ukpong, 2000; Waugh, 2000). The available soil phosphorus content is adequate for the optimal crop production and thus phosphorus fertilizer application is required in these gully soils, especially where is lacking. The low values of exchangeable sodium in middle and lower slopes may be due to course texture of these soils which permit extensive leaching of excess soluble salts. This supports the findings of Egbuchua, 2014. Whereas, Edemet,al, (2012) reported that Low Na content is adequate for plants whereas, high content of Na can destroy soil structure and can be dangerous to plant.

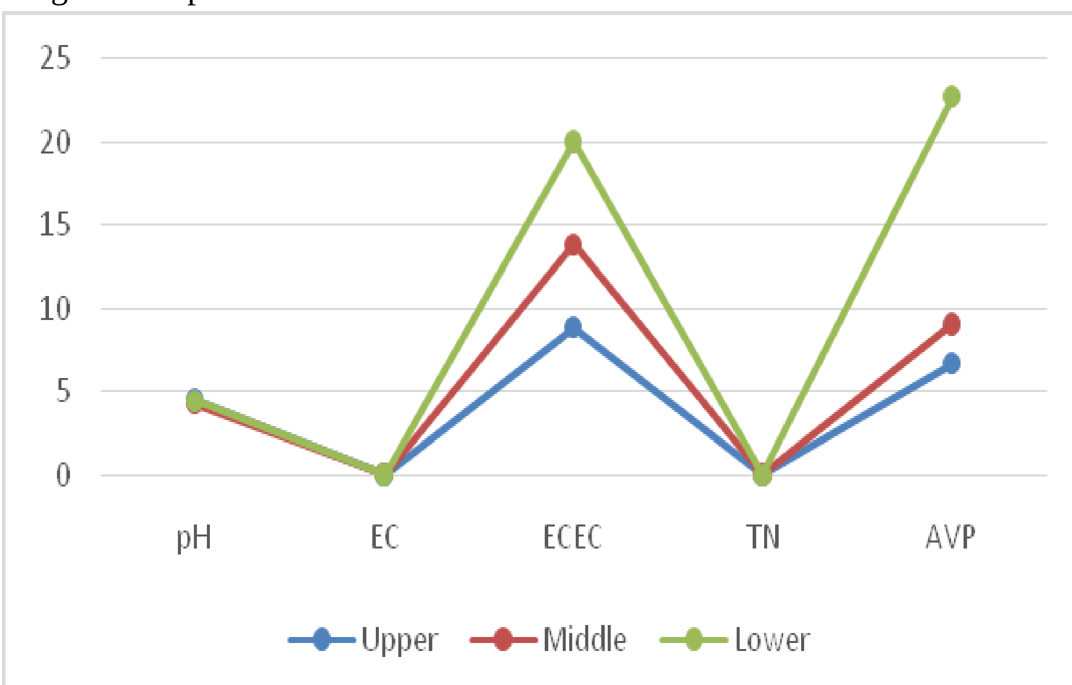

Fig.3 Content of pH, EC, ECEC, TN, AVP in the farms

The mean values of exchangeable cations (Ca, Mg, Na and K) revealed that the gully farms contain base elements with exchangeable calcium (ca) being the most abundant cation in the soil, with values ranging from 4.8 to 22 at farm (cmol/kg) with the mean value 9.8 (Cmol/kg) where upper slope account for 5, middle slope for 6.6 (cmol/kg) and lower slope for 11.5 (cmol/ kg) and at farm B, the upper slope accounted for mean values of 3.2 – 5.7, middle slope 5.2 and lower slope 5.2 – 5.3.The values of exchangeable potassium were between 0.025 cmol/kg to 0.39 cmol/kg across all farms in the top and sub soils. The exchangeable potassium mean values in the different slope segments were 0.09, and 0.19 (cmol/kg) across all the farms, showing increase in potassium down the slope. The mean values of exchangeable potassium above the critical limit of 0.2cmol/kg considered adequate for most agricultural crop. The mean values for exchangeable magnesium ranged from1.68 cmol/kg to 3.3 cmol/kg on the soils of all gully farmlands and had a minimum value of 1.68 at the upper slope, 1.85 at middle slope and 0.19 at lower slope. The research indicated richness in magnesium content down the slope.

This indicated its importance because some of the magnesium will be made available for plant use and magnesium is known to improve plant growth. These observations agreed with the work of Edem et al (2012) on erodibility of soils along a toposequence. Mg less than 1.5cmol/kg are regarded as critical level for fertile soil (Udo et al, 2010), in the entire study area, the arrangement in order of magnitude includes Ca, Mg^{2+}, K and N^{a+}. These findings agree with Boh, McNeal and O[1]conor (2001) that this order is a property of productive agricultural soils and are problematic to ion-imbalance for plants.

Variations in Soil Physicochemical Properties between gully-impacted sites and control plots

The result of the student-test statistic revealed that the p value of 0.000434(two-tail) is less than 0.05, and calculated t of 4.95 is greater than critical t-value of 2.2(two-tail) and so we reject the null hypothesis and accept the alternate which states that there is a significant variation in the physicochemical properties of soils between the gully-impacted sites and control plots.

	SAMPLE 1	***SAMPLE 2***
MEAN	41.58333	24.16667
VARIANCE	910.9924	

OBSERVATIONS	12 12
PEARSON CORRELATION	0.963348
HYPOTHESIZED MEAN DIFFERENCE	0
DF	11
T STAT	4.951879
P(T<=T) TWO-TAIL	0.000434
T CRITICAL TWO-TAIL	2.200985

Crop Production

In Farm A, the mean of lower slope production of crop (weight) was 11.4 as the highest and lowest at the upper slope with 4.7kg weight. In farm B, the upper slope was 5.1kg, middle slope 17.8kg, and 10.25 kg. Farm A records higher yield with mean value of 8.25±1.9kg and farm B had 7.75±1.5kg. In both farms the gully sites had increasing production down the slope with the highest of 14.30kg at the lower slope of farm B and the highest mean value of crop weight of 10.25kg. This shows that decreasing chemical properties from the lower slope up to the upper slope leads to variations in distribution of crop production within the soil area.

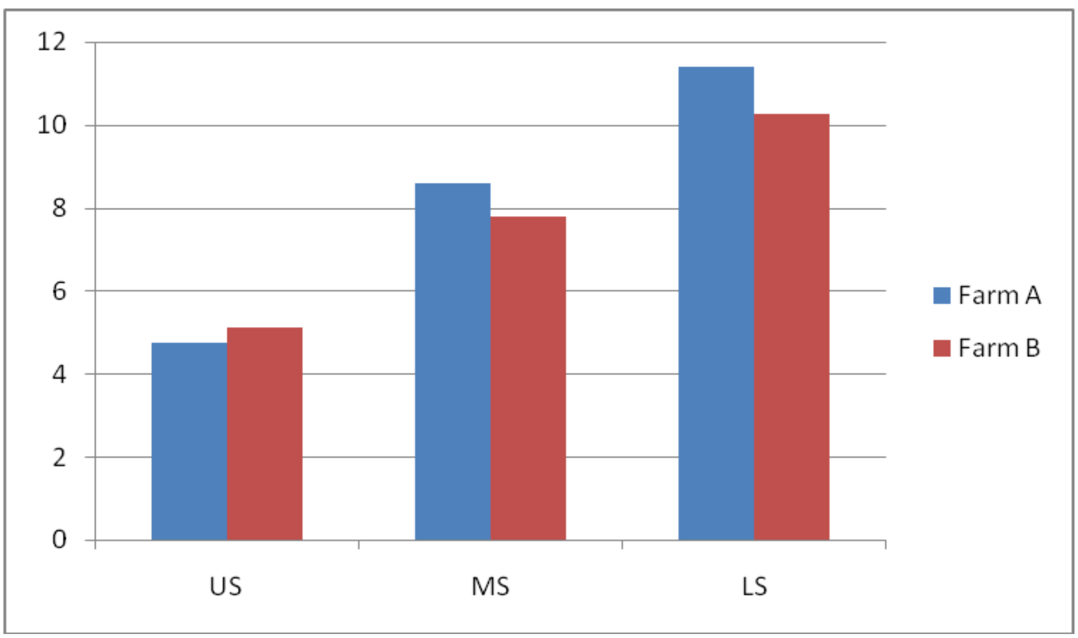

Fig.4. Distribution of Crop production in gully farms along the toposequence

Regression Analysis of Crop-Soil Relationship in the gully farms

The analysis is on the effect of soil components. (sandx1, siltx2, clay x3, pH x4, ECx5, OMx6, TNx7, AVPx8, Cax9, Mgx10, Nax11, Kx12, Eax13, ECECx14, B.sat) on crop production (y). The result indicated that each of the soil component contribute differently to crop production component.

The result of the study is summarized in equation 1-15 thus:

$Y= 15.641-0093X_1$----------------1

$Y= 11.102- 0.157X2$--------------2

$Y= 9.799-0.42X3$------------------3

$Y=10.020-0.044X4$----------------4

$Y=11.357-0.220X5$----------------5

$Y=18.532-0.717X6$----------------6

$Y=8.438-0.70X7$-------------------7

$Y=7.412+0.147X8$-----------------8

$Y=5.384+0.685X9$-----------------9

$Y=3.970+0.723X10$---------------10

$Y=5.157+0.344X11$---------------11

$Y= 3.953+0.757X12$--------------12

$Y= 9.750-0.619X13$---------------13

$Y=2.152+0.902X14$---------------14

$Y=-19.629+0.914X15$-------------15

Outputs will increase by -0.093 units, -0.157 units, - 0.42units, - 0.044 units, -0.220 units, - 0.715units, -0.70 units, 0.147units, 0.685units, 0.723units, 0.344units, 0.757units, -0.619units, 0.902units, and 0.914 units respectively for every one unit increase in sand, sit, clay, PH EC, OM, TN, AVP, Ca, Mg, Na, K, Ea, ECEC and B.sat respectively.The coefficients of determination give the percentage explanation achieved by each of the independent variables. The result of the findings reveal that sand contributes 7.0%, silt contributes 0.17%, clay contributes 4.34%, OM contributes 51.63%, TN contributes o.49%, AV.P contributes 2.15%, Ca contribute 46.98%, MG contributes 52.25%, Na contributes 0.117%, K contributes 57.3%, Ea contributes 38.33%, ECEC contributes 81.32% and B.sat contributes 83.44% to the production of cassava in (Kg/m) at the gully – impacted farmlands.

Plate 1: Gully-impacted farmland/harvested cassava tubers

Conclusion

This study employs cross disciplinary and multifaceted tools to understanding the phenomenal processes and impact of gully erosion on soil properties and crop yield. The results of the study showed that variations exist in particle size distribution, organic matter content and chemical properties of the study area. The reason for this is gully expansion that has altered the pattern of soil distribution in the landscape. The study discovered differential values within series of variation in soil properties and emphasizes on the need for urgent adoption of soil suitability index from the available data to ensure sustainable crop production.

Therefore this research recommends that:

- There is need to invest into producing ecological baseline data since it is lacking in Ata ObioAkpa which covers every fact of the environment. Creating biophysical and chemical data bank is pivotal and could be achieved through detailed land survey (soil, water, and the environment) as well as evaluation activities of the environment.

- Early warning signals, environmental literacy and monitoring tools should be provided to farmers in order to assess and develop their status on soil-crop understanding and vulnerability to gully menace and that once degradation is beyond control, it may be very costly to reclaim the nutrient-rich land. Therefore, the need to crop rotation for nutrient regeneration and gully control should be announced.
- Fertility of soil should be checked and where there are gaps to be filled in the property content or vital nutrient constituent, there is need for detailed land evaluation and suitability studies using Geographic Information technology. GIS would display this using a clearer and understandable agro-environmental model.
- An adequate level of theoretical framework such as integrated agricultural development and soil management approach which is a multidimensional strategy should be applied to facilitate agricultural development involving effective land use planning, soil management practice, stakeholders' incorporation, academia's philosophy, implementation and monitoring of effective agro-environmental policies and socio-logical ideas, among others. This will enhance all-round development of the resource-base of the agro-ecological zone.

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