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Agro-ecological Assessment of the Preponderance of Rill Erosion Channels under Different Land Cover Types in Humid Tropics of Akamkpa, Southeastern Nigeria

Peter Ereh Oko[1], Oruk. Ohon Egbai[2], Brian Usibe[3] Benjamine Ayua Ambe[4], Christopher Abua Ochiche[5]
[1]Department of Environmental Resource Management, University of Calabarokopeter36@yahoo.com
[2] Department of Environmental Resource Management, University of Calabar egbaioruk@yahoo.com
[3]Department of physics, University of Calabar, Calabar. Email: brianonics@yahoo.com
[4]Department of Environmental Education, University of Calabar. ayuambe3@gmail.com
[5]Department of Geography and Environmental Science,University of Calabar .abuaochiche@yahoo.com
Corresponding Author: egbaioruk@unical .edu.ng, egbaioruk@yahoo.com

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ABSTRACT

Agro-ecological assessment of proliferation of rill erosion channels in the humid tropic was conducted between January and July 2022. The purpose of the study was to seek possibility of preventing proliferation of rill erosion channels using a variety of crops; vetiver grass, potato plant, groundnut and fallow vegetation in erosion control. Different land slopes of 4, 5 and 6 per cents representing blocks 1,2 and 3 were used for the study. Soil samples were collected from each unit for laboratory determination of soil textural characteristics. Plots dimension of 10m x 80m were delineated on each slope to form a block. Sub plots of 10m x 10m were delineated from each block for each crops cover types. In-situ measurement of parameters, *viz;* number of rill erosion channels, length, width and depth of channels were accomplished. The total number of rill channels from each crops' plot was statistically analyzed to determine their Coefficient of Variation (CV). The CV values for vetiver, potatoes, groundnut, fallow vegetation and control plot indicated; 40.50%, 31.11%, 60.62%, 38.00% and 62.50% respectively. Result of channel characteristics showed that fallow plot recorded the lowest number of channels of 1.8, width of 2.3cm and length of 142.5cm respectively. Average length and depth recorded in vetiver plots are 143cm and 1.6cm, Potatoes has a total depth of 2.2cm and length of 194.3cm. Similar result was recorded in fallow plot, indicating that vetiver, potatoes and fallow vegetation exhibited similar erosion control potential. Conversely, the highest length, width and depth and number of rill channels were traced to control plot with a mean of 3.8 spillways, depth of 4.8cm, width of 25.8cm and mean length of 312.5cm seconded by groundnut plot. Implying, soil protection as well as crop production can be guaranteed with the right choice of crops in the humid tropics.

Key words: Fallow vegetation, land cover, Rill erosion channels, slope spillways.

1. INTRODUCTION

Humid tropical region is distinct from other regions due to its geographical peculiarity. Humid tropic has an exceptionally high amount of rainfall, sufficient vegetation cover and undulating land surface which determines landscape characteristics. Rill erosion channel is interchangeably used in this study to represent spillway formation. Spillway simply means the path(s) created by erosion channel, occasioned by rainfall and its associated runoff. High rainfall is a major characteristic of the humid tropical region where Akamkpa belongs. Rain starts from late March to October and riches its climax in the month of June and September. Average annual rainfall reaches 2700mm; the area has eight to nine months of raining season and a short period of three to four months of dry season. It has a mean annual rainfall of 2500 – 3000mm with a mean annual temperature of about 26.1^{0}C and a relative humidity of 85% [1]. Rill erosion channel is a common feature in the tropical humid landscapes characterized by undulating and sloppy land configuration capable of facilitating accelerated erosion. The fact that such landscape can influence soil erosion implies that soil nutrient will be lost and food production will be adversely affected.

In view of the growth rate of Nigerian population amid fixed landmass and the inevitability of ensuring sufficient food supply, it's pertinent to protect the limited landmass using appropriate soil protection mechanism in order to guarantee sustainable food production. Studies have suggested measures that can enhance soil protection. Edem and Okoko [2] employed vitiver grass to check soil loss in an undulating land terrain of Uyo, Nigeria indicating that crops or plants cover can be effective in stabilizing susceptible land terrains. In agro-ecological landscape, studies have equally shown that certain varieties of crops can be used to control erosion menace. Ogogo *et al* [3] used melon, cocoyam and other crop varieties to control soil erosion in Cross River State, Nigeria. Similarly, Anikwe et al. [4] used groundnut to reduce erosion perturbation at Enugu Nigeria. Implying that, crops can also be useful in stabilizing vulnerable land terrains. Akamkpa is one of the major food producing communities in Southeastern Nigeria. In recent times, food production has drastically declined to the extent that farmers sort alternative ways of producing food at subsistent level in order to address their food production needs. The noticeable decline in food production has been attributed to poor soil quality. Unarguably, soil nutrient loss and the associated incoherent nature of its textural characteristics are worsened by the action of soil erosion. The manifestation of soil degradation in the tropics begins with soil erosion by water [5] in the form of sheet or rill. Runoff from agro-dominate landscape is usually accompanied by loss of huge amount of nutrients. Nutrients such as nitrogen and phosphorus from agricultural lands progressively find their ways into adjacent streams or other water sources to cause pollution. In extreme condition, eutrophication sets in, due to gradual enrichment of nutrient pollutants into water sources. [6]. Runoff on agricultural lands are usually facilitated by a number of factors such as inadequate surface cover by crops, planting method, crop type, soil texture and slope gradient. Egbai *et al* [7] posited that the effect of runoff on agricultural land is mostly experienced at the beginning of the rains when the ground is not sufficiently covered with vegetation exposing the soil to effect of weather elements. Exposure of the soil to the vagaries of weather elements may result in the loss of nutrients, poor crop growth and yield and the distortion of land surface. Rim-Rukar [8] emphasized that runoff from agricultural sites does not only distort land surfaces but a major source of soil pollution. He enumerated the effect of soil erosion to include loss of fine soil and breakdown of soil structure. Arguably, the formation of rill erosion channels may not be dependent on ground cover potentials of crops or vegetation alone but a combination of other factors example texture of soils and slope condition. The study aimed to evaluate the efficacy of crops' cover types in the control of soil erosion in the tropics. To this end, groundnut, potatoes were evaluated amid vetiver, fallow vegetation and bare land which served as control plot.

2. METHODOLOGY

2.1 Study area

The study area is Akamkpa in Cross River State, Nigeria. This area lies in longitude $08^0\ 34^1\ 31^{11}$ E of the Greenwich Meridian and latitude $05^0\ 31^1\ 11^{11}$ N of the Equator. Rainfall and relative humidity are usually high. High rainfall is a major characteristic of the humid tropical region where the study area belongs. Rainfall starts from late March to October and riches its climax in the month of June and September, the area has eight to nine months of raining season and a short period of three to four months of dry season. Rainfall is usually measured with the use of rain gauge. The area has mean annual rainfall amount of 2500 – 3000mm with a mean annual temperature of about 26.1^0C and a relative humidity of 85% [1] The topography is quit undulating, typifying general relief condition of the humid topical environment [9]. This type of terrain encourages profound removal of soil materials in the event of rainfall [5]. Rill erosion metamorphosed from sheet erosion to gully erosion [10]. In the humid tropics with relatively high amount of rainfall, the predominance of astounding gully sites is assuming a worrisome dimension, as socioeconomic activities are usually implicated. Gully formation in the tropics usually starts unobtrusively and assumes uncontrollable dimension that requires costly intervention plan hence the need to identify its source so as to prevent it from developing into gully.

2.2 Materials and Methods

Land preparation for this study was accomplished by traditional method of clearing with cutlass prior to crop planting in January, 2022. The selection of site was based on slope condition that fell within the range of 4 to 6 per cent slopes. The topography of the area is typical of humid tropical environment. Three experimental units (labeled; 1, 2 & 3) measuring 100 X 80m were delineated in each of the locations. Subsequently, five (5) subplots of 10 X 10m were demarcated. Each subplot carries one crop separated by 5m to avoid possible interference by adjacent plot. The bare land plot otherwise refers to control plot was artificially influenced by the use of hot water and the application of condemned petroleum product (diesel). This was done in other to make the soil nutrients and microorganism incapable of exerting their influence thereby leaving the affected portion bare throughout the period of the experiment. Soil samples were randomly collected with the aid of soil auger for laboratory determination of their particle size distribution [11].

Vetiver grasses were collected and planted in the field in March 2022. Similarly, the collection and planting of materials were accomplished within three days. Potatoes stems and groundnut seeds were planted the same day the vetiver grasses were planted using their recommended planting distance [12]. In each of the sample plots, the various cover crops were planted, however a control plot without cover crop was established in each of the experimental site. The control plot represents a bare land condition suggestive of an area battered profoundly by human activities. Monitoring of rill erosion channel begins with the understanding of the status and severity of erosion perturbation [13], after an intense rainstorm. Edem and Okoko **[2]** suggested a walk around the study area to identify where spillways or rill erosion channels have taken place. The number of spillways, length, width and depth were measured on monthly basis for a period of four months.

2.3 Data Collection

Soil samples were randomly collected with the aid of soil auger for laboratory determination of their particle size distribution [11]. In-situ measurement and determination of spillways, were done to reflect the following parameters; number, length, depth and width of spillway on monthly basis with the aid of a meter rule placed at the beginning (head), middle and end of erosion channel. The averages were obtained as cumulative values, collected from each of the sites, divided by the total number of experimental sites. This was used to calculate the length, width and depth of erosion channel.

3. RESULT AND DISCUSSION

Table 1: Result of soil textural characteristics (Soil physical properties of crops' plots)

LOCATION	CLAY	SILT	SAND
Block 1	60.8	8.0	31.2
Block 2	62.3	7.3	30.4
Block	62.5	7.5	30.0
Range	60.8 – 62.5	7.3 – 8.0	30.0 – 31.2

Table 2: Result of Average monthly record of measured parameters across the experimental sites (cm)

S/NO.	Crops	No. of spills				Average Depth (cm)				Average Width-cm				Average Length (cm)			
		Apr	Ma	Jun	Jul	Apr	Ma	Jun	Ju	Apr	Ma	Jun	Ju	Apr	Ma	Jun	Ju
1	Vetiver	1	2	2	3	1.0	1.2	1.5	3	2	3	8	12	150	152	120	50
2	Potatoes	1	2	3	3	2.3	1.5	2.0	3	14	16	19	20	168	169	180	260
3	Groundnut	1	3	4	5	1.3	2.6	3.0	3.5	23	24	26	27	244	260	350	360
4	Fallow	1	1	2	2	2.2	1.1	2.0	5.0	5.0	6	8	8	144	131	150	150
5	Control	1	3	5	6	3.0	3.1	3.0	10	25	25	25	28	246	256	368	380

Table 3: Mean total of measured parameters across the plots

S/NO	Crops	Total spills	Total depth	Total width	Total length
1.	Vetiver	2.0	1.6	6.3	143
2.	Potatoes	2.3	2.2	17.3	194.3
3.	Groundnut	3.3	2.6	25.0	303.5
4.	Vegetation	1.8	2.6	2.3	142.5
5.	Control	3.8	4.8	25.8	312.5

Figures 1 & 2 showing Number, depth and width of channels produced by different crop cover types

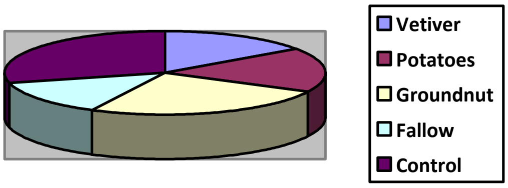

Figure 1: Pie chart showing extent to which different crops' cover types response to erosion perturbation

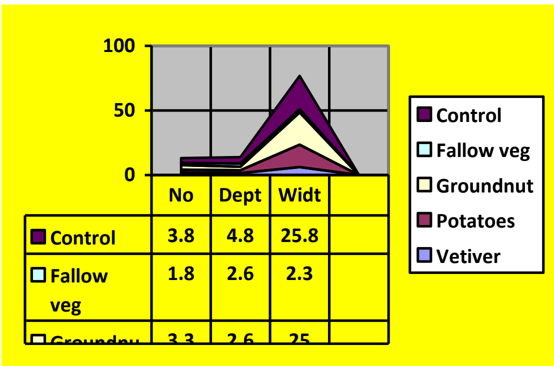

Figure 2: showing level of susceptibility of different cover types to erosion

Table 4: showing range, mean, variance, standard variation and coefficient of variation of the various crops potential in erosion control

Crops	**Range**	**Mean**	**Variance**	**Standard Deviation(SD)**	**Coefficient of Variation(CV)%**
Vetiver	1 – 3	2	0.66	0.81	40.50
Potatoes	1 – 3	2.25	1.58	0.70	31.11
Groundnut	1 – 5	3.25	3.90	1.97	60.62
Fallow	1 – 2	1.5	0.33	0.57	38.00
Control	1 – 6	7.2	20.79	4.56	62.50

The physical properties of soil showed that sand values ranged from 60.8 to 62.5, while silt and clay fractions ranged from 7.3 to 8.0 and 30.0 to 31.2 respectively. The range of the particle size distribution showed identical textural classes. From the classes obtained sand and clay contents indubitably determine soil characteristics of the area. However, the most dominant particle size is the sand fraction and when soils are sandy soil sharing is facilitated because of the friability of the particles. There is no doubt that with the amount of clay fraction in the soil, cohesion can be enhanced to an extent but cannot eliminate soil sharing that influences soil erosion. The result of textural characteristic reveals the preponderance of rill erosion channels in the area. Rill erosion metamorphosed from sheet erosion to gully formation that adversely affects land use system, example; agriculture, residential, transportation, industrial and tourism.

. The environmental impact of gully erosion cannot be easily quantified as they ranged from economic to ecological making protection of soil at the point of rill erosion inevitable. In the context of agro ecosystem, the use of crops for erosion control has ecological and economic significance; food production on one hand and soil protection on the other.

The role of cover crops in erosion control cannot be overestimated giving its food production, nutrient recycling and soil stability benefits [4]**.** Different ground covers have different soil protection potentials; the higher the length, breadth and width of crops' leaves, root and stem sizes the higher the content of its residues [10]**.** The quality of humus content in the soil is dependent on the quality of the crops' residue that enables it stabilize the soil against environmental influence. The quality of plants residues produced from leaves, roots and stem respectively play prominent rule in stabilizing the soil and enhancing cation exchange capacity [13]. Nutrient and organic matter stability in the soil is relative to soil enriching plant residues. The leaves fall enhances soil coherence and the more coherence or consistent the soil is, the more invulnerable it is to erosion perturbation. In agro-ecological condition, the amount of cascaded soil materials from runoff is considerably high where ground cover is inadequate. Under this condition, there is no possibility of separating rural people from farming, hence the need for assessment of crops with fast growing and efficient soil stabilization characteristics.

Different crops have different morphological arrangement and different root systems. These features play prominent role in protecting the soil against rainfall impact as well as enhance nutrient stabilit. The most essential nutrient elements required for plant growth are soil dependent [6] thus, where soil erosion is involved soil nutrient stability is implicated.

Table 2 revealed the effectiveness of various plot in combating erosion. Result showed that the highest number of spillways was recorded in control plot with a range of 1- 6 seconded by groundnut plot with a range of 1 - 5. The least range was recorded in fallow plot while the vetiver and potatoes plots have similar ranges. The lowest length of rill was recorded in fallow plot seconded by vetiver and potatoes plots. On the other hand, the lowest number of spillways was obtained in fallow plot seconded by potatoes plot. Table 3 also showed similar result. Mean total of measured parameters (No, of erosion channels, length, width and depth of channel) were examined. From the tables 2&3, crops components like, leaves, roots and stems no doubt performed critical role in soil protection in view of the result of the measured parameters. These parameters represent important plant's features that enable it protect the soil from erosion. Spillways connote erosion channels which are determined by the nature of land slope, soil texture, runoff and nature of vegetation cover. The number of spillways in a plot reveals the potential of the crop cover in soil protection against erosion and loss of soil fertility [10, 14]**.** Figure 1&2 show the response and susceptibility of different crops cover types to erosion perturbation.

In Table 3, fallow plot recorded the lowest mean value of spillways 1.8, the least channels width of 2.3cm and the least length of 142.5cm. Similarly, vetiver, potatoes and fallow plots recorded mean values of 2.0, 2.3 and 1,8 numbers of spillways respectively. Meanwhile the mean length and depth recorded in vetiver plots are 143cm and 1.6cm, potatoes has a total depth of 2.2cm and length of 194.3 while fallow vegetation recorded 2.6cm depth, 2.3cm width and a length of 142.5cm respectively. It shows that vetiver, potatoes and fallow vegetation plots exhibited similar potential in erosion control. Crop cover with minimum number of rill channel, length, depth and width of channel is an indication of its potential to interfere with rain drop that breaks soil peds or aggregate using its leaves and the stem that enables it withstand the effect of rain storm action and the roots that penetrate the soil thereby creating space for infiltration and reducing runoff.

Table 4 shows some important statistical parameters including standard variation and coefficient of variation. Result of standard deviation (SD) of crops was recorded to include; vetiver grass 0.81; potatoes 0.70; groundnut 1.97; fallow vegetation 0.57 and control plot 4.56 respectively. From the result, it is obvious; the highest coefficient of variation is associated with crops with least soil protection potential. Similarly, result of coefficient of variation (CV) shows that control and groundnut plots have CV of 62.50% and 60.62% respectively while CV values of vetiver, potatoes and fallow vegetation plots indicated 40.50%, 31.11% and 38.00% respectively.

Tables 2and3 show that a thicker or maximum ground cover offers adequate soil protection than light or minimum ground cover. The various parameters increased progressively across different crops' plots. As the leaves protect the soil from the vertical rain drop impact, the roots protect the soil from the effect of horizontal movement of water by enhancing soil coherence through the binding effect of the root system.

Farming in the tropics is often implicated due to the complex heterogeneity of the humid tropical landscape which generally underpins huge amount of soil loss as a consequence of exceptional degree of rainfall and runoff phenomena. Runoff is usually influenced by the amount and duration of rainfall, topography, soil type and land cover type. The later has significant contribution in the control of erosion in the humid tropics where Akamkpa belongs. The concern is always in the land cover density. In reality, the more the cover density or thickness of the vegetation the lesser the amount of runoff, soil and nutrients losses from the affected land.

Conversely, Ries *et al.* [15] averred that, increase in the vegetation cover does not imply a clear reduction of erosion processes as some landscapes can possibly suffer increasing erosion processes even under vegetation cover. Erosion processes are often influenced by large scale reduction of vegetation cover in the humid tropics to the extent that the reciprocation can exert serious environmental consequences that are often difficult to manage. Thus, soil erosion by water is capable of influencing serious geo-environmental problem in the South-eastern Nigeria causing both on-and off – site effects. The former has direct effect on the productive capacity of the land with implication on the demand for higher farm inputs such as high quality planting materials, fertilizer, herbicides amongst others to foster better yields.

The most dominant off-site effects include deposition of materials into reservoirs and the clogging of the water ways thereby impeding the flow velocity of affected local water sources and threatening continuous existence of such water bodies due to sedimentation and siltation. This does not go without adverse health and environmental consequences [16] in view of obvious water quality impairment resulting from the introduction of contaminants into the water body. Apart from soil loss issue which is associated with the phenomenon of soil erosion, water pollution is an important source of concern especially in the context of rural population of Akamkpa where the study was carried out. Therefore it is necessary to evaluate land cover type with a view to determining the most effective and efficient cover type that can best suit the highly vulnerable humid landscape of Akamkpa. However, sufficient vegetation cover and the nature of landscape structure are critical elements in the determination of the degree of runoff and loss of soil materials that are responsible for susceptibility of soil to erosion.

Spillway refers to path(s) through which water overflows or safely drains out of the land after rainfall event. Spillway formation is a dominant feature of an undulating land terrain especially when such landscapes are not sufficiently covered with vegetation. As a precursor to sheet and rill erosion, they deserve serious attention in order to overcome and avert adverse consequences of soil erosion. It is interesting to note that in agrarian landscape the cultivation of certain crops do not only lead to food production but serves as a veritable source of soil protection from the devastating effect of water erosion in the context of humid tropical agro-ecological setting. Studies have proved that crops can be used to control erosion menace [3]. Anikwe *et al*. [4] used a variety of crops to reduce erosion perturbation at Enugu while Edem and Okoko [2] have used *vitiver* grass to check soil loss in Uyo, Nigeria..

Amidst many traditional and scientific methods of tackling erosion menace Hartwig and Ammon [17] posited that the adoption of such traditional and scientific practices like moulds, mulching, ridges, building barriers, crop rotation in combination with efficient utilization of important crops protection potentials in soil erosion management will be cost effective. It is noteworthy that some soil erosion control measures have failed to yield result due to cost implication, low level of technology, lack of awareness, bio-physical factor and lack of political will of government amongst others. Nevertheless, the limitations associated with disease infestation that usually implicate crops growth and development perhaps may constitute part of the reason for none utilization of some important soil erosion control measures. Disease condition occasioned by mulching would no doubt slow down interest. According to Hortwig and Ammon (2002) **,** the use of mulching material often becomes breeding ground for crops pest. There is no doubt that an average local farmer lacks the capacity to practically adopt any measure that is costly to maintain, therefore employing a simple, affordable and compatible soil loss ameliorating measures like the use of simple and affordable crop for soil erosion control will be worthwhile and practicable [18]. Soil erosion poses detrimental impact on macro and micro organisms exposing them to the vagaries of unfavourable environmental element. Egbai et al [19] averred that soil nutrients are usually implicated, most worrisome is the fact that all soil types are amenable to erosion perturbation provided such soils are reasonably subjected to its devastating effect.[20]

Akamkpa remains one of the major crop production strongholds of the people of Southeastern Nigeria, thus affording local farmers the best way to effectively and efficiently protect their soil in the humid tropical landscape will stimulate interest in agricultural production and ensure adequate protection of soil entities.

4. CONCLUSION

Agricultural production in the tropics is bedeviled by a number of factors like nature of the topography, density of ground cover, nature of the soil and rainfall intensity. Erosion is facilitated by natural and anthropological factors that expose the soil to the vagaries of environmental elements. The soil physical characteristics clearly showed homogeneous soil characteristics, thus creating similar environmental condition for the manifestation of their real potentials. Control plot represents a bare land or an area already exposed to vagaries of nature. Results showed that control plot in this context yielded substantial erosion perturbation as a consequence of human activities while vetiver and potatoes plots were resistant to erosion. This shows that crops can prevent extreme runoff and potatoes on 4 to 6 slope condition while fallow vegetation and vetiver grass will help protect vulnerable portion of land including bare surfaces that are recuperating invariably protects the soil against erosion perturbation. This is evident in the number of spillways or rill erosion channels and other associated parameters; like length, depth and width of channel. The result of erosion channels produced by each crop showed that fallow plot recorded the lowest average number of channels of 1.8, width of 2.3cm and length of 142.5cm respectively. The average length and depth recorded in vetiver plots are 143cm and 1.6cm, Potatoes has a total depth of 2.2cm and length of 194.3cm respectively. Similar result was recorded in fallow vegetation plot indicating that vetiver, potatoes and fallow vegetation exhibited similar erosion control potential. Conversely, the highest length, width and depth including the number of rill formations were traced to control/bare plot with a mean of 3.8 spillways, depth of 4.8cm, width of 25.8cm and mean length of 312.5cm. Indicating that land surface that is exposed to vagaries of rain drop impacts is vulnerable to erosion and its associated impact. Comparatively, vetiver, potatoes and fallow vegetation plots exhibited relatively strong potentials in erosion control. To guarantee sustainable food production as well as soil protection in an agro-dominant landscape, the study recommends the use of potatoes on 1% to 6% slope condition while fallow vegetation and vetiver grass will help protect vulnerable portion of land including bare surfaces that are recuperating.

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