IOSR Journal of Research & Method in Education (IOSR-JRME)
e-ISSN: 2320–7388, p- ISSN: 2320-737x Volume 11, Issue 2 Ser. V (Mar. – Apr. 2021), PP 47-52
www.iosrjournals.org

Water Quality Study of Farm Runoff with Respect to Nitrogen, Potassium and Phosphorus (NPK).

Awotoye, Grace Tina
Department of Agricultural Education, Federal College of Education Okene, Kogi State, Nigeria.

Abstract
Farm runoff is surface water leaving cultivated fields as a result of receiving water in excess of the infiltration rate to the soil. It is a multifactor threat to crop production and the environment. The aim of this study was to determine the effect of runoff on soil nutrients losses and to establish the relationship between the amount of rainfall and runoff. A field experiment was carried out on runoff plots with different cropping systems (sole maize, sole cowpea and maize intercropped with cowpea) as main plots and soil treatment NPK 15.15.15 (Nitrogen, Phosphorus, Potassium) fertilizer and a control plot with no crop and treatment. Four runoff meters were installed for the collection of runoff water, 20cm^3 of the runoff water was taken for analysis and there was direct relationship between the runoff volume and the nutrient losses. The maximum values recorded for the four plots were 7.80cm^3, 8.90cm^3, 7.80cm^3 and 8.20cm^3 for the plots A, B, C, and D respectively. The nutrients decease steadily after each rainfall and runoff thereby establishing the fact that runoff has negative effect on the nutrient properties of the soil.

Keywords: *Farm Runoff, Soil Treatment, Runoff Meter, Soil Fertility.*

Date of Submission: 14-04-2021 Date of acceptance: 28-04-2021

I. Introduction

Soil erosion reduces the agricultural value of lands via physico-chemical degradations. Soil nutrient loss through runoff and sediment, is a major driver for soil fertility decline [13, 19]. The eroded sediments or soil are highly concentrated with crop nutrients, which are washed away from farmlands. Erosion-based constraints coupled with unfavorable climatic conditions define significantly the productivity of farming systems in kogi state. Soil erosion leads to extreme losses of economic and environmental resources which negatively impact the economies of affected area [8, 20]. On-site consequences are directly observed on crop production as well as soil properties, affecting adversely the ability of the soil to respond to management practices with time. Durán et al. (2009) defines Farm runoff as surface water leaving cultivated fields as a result of receiving water in excess of the infiltration rate of the soil. Before runoff can occur, the precipitation must satisfy the demands of evaporation, interception, infiltration, surface storage, surface detention and channel detention. That is when the rate of precipitation exceeds the rate at which water may infiltrate into the soil. After infiltration rate is satisfied, overland flow begins and the depth of water builds up on the surface until the depressions are filled then farm runoff begins hence removing the top soil which are loose in nature and the plant nutrient present in the top soil. The characteristics of runoff are determined by some factors, they either increase or reduce runoff and these are; rainfall intensity, duration of rainfall and drop size, type of precipitation, frequency of intense rainfall, shape, size and slope of catchment area.

Nutrients are elements essential to plant growth [7]. Plant roots absorb nutrients—including water, oxygen, and others—from the soil. As crops grow and are harvested, they gradually remove the existing nutrients from the soil. Over time, most soils will require additional nutrients to maintain or increase crop yield. Plants utilize nutrients in different ways, and each plant has a different set of nutrient requirements [16]. How, where, and when plants utilize nutrients can greatly affect the overall yield and plant production. For a farmer seeking to maximize crop yields and lower input costs, it is essential to understand a crop's nutrient requirements. The most abundant nutrients in plants are carbon; hydrogen, and oxygen, plants also utilize other nutrients commonly referred to as macronutrients and micronutrients. In agricultural production, the focus generally rests on the three primary macronutrients—nitrogen (N), phosphorus (P), and potassium (K)—because of their relative abundance in plants. This report focuses on the three primary macronutrients (nitrogen, potassium and phosphorus) because of the volume used in agricultural production and the relative potential for environmental harm if they are overused [13].

The nutrient loss through runoff and sediment are important threats to soil nutrient depletion in Kogi State and the eroded sediments or soil are highly concentrated with crop nutrients, which are washed away from farmlands. As a result of this, most soils in Kogi are highly degraded such that specific integrated management practices involving organic and inorganic amendments are required. Nitrogen (N) and phosphorus (P) are essential nutrients to plants. Nitrogen is a one of the major elements for plants growth and development that have an important role in plant nutrition and therefore is the yield-limiting factor for plant growth in many areas especially in low organic soils (De Pascale *et al.*, 2006). Phosphorus [P] is a major element and performs vital functions for sustenance, growth and development of plants. It is involved in several key plant functions, including energy transfer, photosynthesis, transformation of sugars and starches, nutrient movement within the plant and transfer of genetic characteristics from one generation to the next. Deficiency of Phosphorus in soil severely affects the plant metabolism and in turns their yields.

It is a multifactor threat to crop production and the environment. The nutrients lost through runoff indicate significant cost because of the need for replacement to enhance sustainability of cropping systems. In small-scale farming systems, this cost is not considered due to lack of relevant information. Thus, its quantification can help different stakeholders to adopt the most effective soil and crop management practices to reduce loss and improve crop productivity [7]. The aim of this study was to determine the effect of runoff on soil nutrients losses and to establish the relationship between the amount of rainfall and runoff

II. Material And Methodology

Study Area

The experiment was conducted at the experimental farm of Agricultural Education department, Federal College of Education Okene, Kogi State. The study area Kogi State is located in the middle-belt of Nigeria with an average maximum temperature of 33.2^oC and average minimum of 22.8^oC (Kogi state MDGs and multilateral relation office, 2000). Lokoja, the state capital, is generally hot throughout the year with an average relative humidity of 68-70%. Hence, Okene shares the tropical features such as high temperature, low and unsteady rainfall and low irregular relative humidity. The area is characterized by two cropping seasons: March to October as the major season and November to February as the minor season as a result of bimodal rainfall regime. Annual rainfall ranged from 1016 to 1524 mm. The vegetation of the state consists of mixed leguminous (Guinea) woodland to forest savannah. Kogi State has a total land of 28,313.53 square kilometers and a projected population of 3.3 million people (NPC, 2006). It lies on latitude 7.49^0N and longitude 6.45^0E with a geological feature depicting young sedimentary rocks and alluvium along the riverbeds. The state features ferrasols soil type (Ogunjowo, 2000). Agriculture is the mainstay of the economy and the principal cash crops produced are: Palm oil, Cashews, Groundnuts, Maize, Yam, Cassava, Rice, Benny Seeds and Melon. (Ogunjowo, 2000).

Experimental design

The catchment area of 10m by 10m was cleared for this purpose. Four mini runoff labeled (A, B, C, D) meters made of wooden plank were constructed and installed at four different points on the catchment. The runoff meters were 1mm by 1mm apart with inter- space width of 0.4m, these were installed in the soil to a depth of 10cm. A PVC pipe of 0.2m diameter was connected to the runoff meter to convey the runoff water to the collectors (bucket) installed below the tip of the pipe. A rainguage which ranges from 0 to 35mm was installed to collect raindrops and the volume of the raindrops collected can easily be read from the graduated scales. The measurements were repeated for every rainfall during the period of the experiment i.e. September to October.

The experiment comprised of two factors: cropping systems (Maize + cowpea intercrop, sole maize, sole cowpea & control) and soil treatment (NPK 15.15.15). Maize + cowpea intercrop were planted in runoff meter A, sole maize in B, sole cowpea in C & control is D. 10g of soil treatment (NPK 15.15.15) was applied by row method two weeks after sowing and another 10g of treatment (NPK 15.15.15) was applied five weeks of sowing.

Sample Collection and Laboratory Analysis

The runoff from the runoff meter drained into a bucket (collector) that was installed below the tip of the pipe, samples of 20ml was taken at each measurement. The samples were taken to the laboratory for analysis so as to determine the nutrient (Nitrogen, Phosphorus and Potassium) losses in the soil from the runoff. For nitrogen determination, 5ml of the collected runoff/water samples was taken, put in a test tube and hot concentrated hydrogen tetraoxosulphate VI acid was added together with one Kjeldahl catalyst tablet to convert nitrogen into ammonium acid, Nitrogen content was then determined by Kjeldahl process [17] (Titrating method). Phosphorus and potassium concentrations in the runoff were analyzed from a thoroughly mixed and homogenized sample 5ml to which 15ml and 10 ml of HCl and HNO_3 respectively were added and digested. Phosphorus and the potassium concentrations were then determined by instrumental (photometry) methods respectively.

III. Results

Rainfall, runoff data as well as percentage of nutrient losses in each plot were analyzed and results presented below.

Table 1: Rainfall and mean Runoff in different plots (cm^3)

Rainfall	Runoff A	Runoff B	Runoff C	Runoff D
3.0	0.15	0.12	0.10	0.18
6.0	0.25	0.10	0.10	0.27
4.0	1.60	1.74	1.65	1.95
10.0	0.16	0.15	0.13	0.18
8.0	0.14	0.13	0.10	0.18
15.0	7.50	8.90	7.80	8.00
13.0	6.80	7.60	7.30	8.10
12.0	2.15	2.60	2.30	2.90
20.0	0.11	0.23	0.11	0.28
23.0	7.50	5.45	4.50	4.65
18.0	5.45	3.86	3.45	5.15
29.0	7.80	8.50	7.70	8.20
42.0	7.65	8.32	7.10	8.80

This shows the precipitation and means runoff from plots A to D. The values of runoff from the individual plots did not vary significantly. The maximum values recorded for the four plots were 7.80cm^3, 8.90cm^3, 7.80cm^3 and 8.80cm^3 for the plots A, B, C, and D respectively. There was direct relationship between the runoff volume and the nutrient losses. There was however some exception where small amount of rainfall resulted in large volume of runoff and vice-versa. This is due to antecedent moisture content, when it had rained previously, a little rainfall resulted into runoff. A case of rainfall of 42cm^3 that should give the highest runoff did not because there had been no rain in the preceding days.

The mean amount of nutrients lost under the different cropping systems and soil amendments are presented in Table 2a, b, and c. The nutrients assessed were the N, P, and K which were applied via chemical fertilizers. The tables show the values of nitrogen, potassium and phosphorus in each plot and bar charts were used to determine the effect of runoff on each of the nutrients as shown in figures 1-3. Nitrogen, Potassium and Phosphorus decease steadily after each rainfall and runoff. The sudden increase observed in 24 September was due to the fact that fresh application of fertilizer has just been applied. It was observed that the nutrient decreases thereafter due to leaching. This results have established the fact that runoff has negative effect on the nutrient properties of the soil.

Table 2a: Rainfall, Runoff and Percentage of Nitrogen in different runoff plots

Date	Rainfall	Mean Runoff	%N_2 A	%N_2 B	%N_2 C	%N_2 D	Mean
6/9/17	3.0	0.15	0.12	0.12	0.10	0.06	0.10
9/9/17	6.0	0.25	0.10	0.09	0.09	0.05	0.08
11/9/17	4.0	1.60	0.07	0.05	0.06	0.04	0.06
15/9/17	8.0	0.16	0.06	0.05	0.04	0.02	0.04
19/9/17	13.0	0.14	0.04	0.04	0.03	0.02	0.03
24/9/17	15.0	7.50	0.22	0.18	0.17	0.02	0.15
27/9/17	13.0	6.80	0.18	0.17	0.15	0.02	0.13
29/9/17	12.0	2.15	0.16	0.14	0.15	0.03	0.12
2/10/17	20.0	0.11	0.16	0.11	0.13	0.02	0.11
6/10/17	23.0	7.50	0.15	0.14	0.12	0.03	0.11
12/10/17	18.0	5.45	0.14	0.11	0.11	0.02	0.10
18/10/17	29.0	7.80	0.13	0.09	0.11	0.02	0.09
26/10/17	42.0	7.65	0.10	0.07	0.10	0.01	0.08

Table 2b: Rainfall, Runoff and Percentage of Potassium in different runoff plots

Date	Rainfall	Mean Runoff	%K of A	%K of B	%K of C	%K of D	Mean
6/9/17	3.0	0.15	15.00	13.80	8.00	8.50	11.33
9/9/17	6.0	0.25	14.50	12.40	7.50	8.10	10.63
11/9/17	4.0	1.60	13.00	12.00	7.00	7.50	9.88
15/9/17	10.0	0.16	12.40	10.10	6.80	7.10	9.10
19/9/17	8.0	0.14	10.20	9.00	6.60	6.90	8.18
24/9/17	15.0	7.50	82.50	74.50	74.50	7.00	59.63
27/9/17	13.0	6.80	72.50	77.00	78.50	7.50	58.88
29/9/17	12.0	2.15	68.00	48.20	54.20	6.40	44.20
2/10/17	20.0	0.11	55.20	46.40	38.50	6.20	36.58
6/10/17	23.0	7.50	51.50	64.20	48.50	5.90	42.53
12/10/17	18.0	5.45	48.50	48.50	46.50	5.60	37.28
18/10/17	29.0	7.80	44.50	40.50	40.50	5.20	32.68
26/10/17	42.0	7.65	26.00	28.50	27.80	4.00	21.58

Table 2c: Rainfall, Runoff and Percentage of Phosphorus in different runoff plots

Date	Rainfall	Mean Runoff	%P of A	%P of B	%P of C	%P of D	Mean
6/9/17	3.0	0.15	15.00	13.80	8.00	8.50	11.33
9/9/17	6.0	0.25	14.50	12.40	7.50	8.10	10.63
11/9/17	4.0	1.60	13.00	12.00	7.00	7.50	9.88
15/9/17	10.0	0.16	12.40	10.10	6.40	6.80	8.93
19/9/17	8.0	0.14	10.20	9.00	6.00	6.60	7.80
24/9/17	15.0	7.50	82.50	74.50	74.50	6.20	59.43
27/9/17	13.0	6.80	72.50	77.00	78.50	5.90	58.48
29/9/17	12.0	2.15	68.00	48.20	54.20	5.90	44.08
2/10/17	20.0	0.11	55.20	46.40	38.50	6.00	36.53
6/10/17	23.0	7.50	51.50	64.20	48.50	5.80	42.50
12/10/17	18.0	5.45	48.50	48.50	46.50	5.80	37.33
18/10/17	29.0	7.80	44.50	40.50	40.50	5.20	32.68
26/10/17	42.0	7.65	26.00	28.50	27.80	5.00	21.83

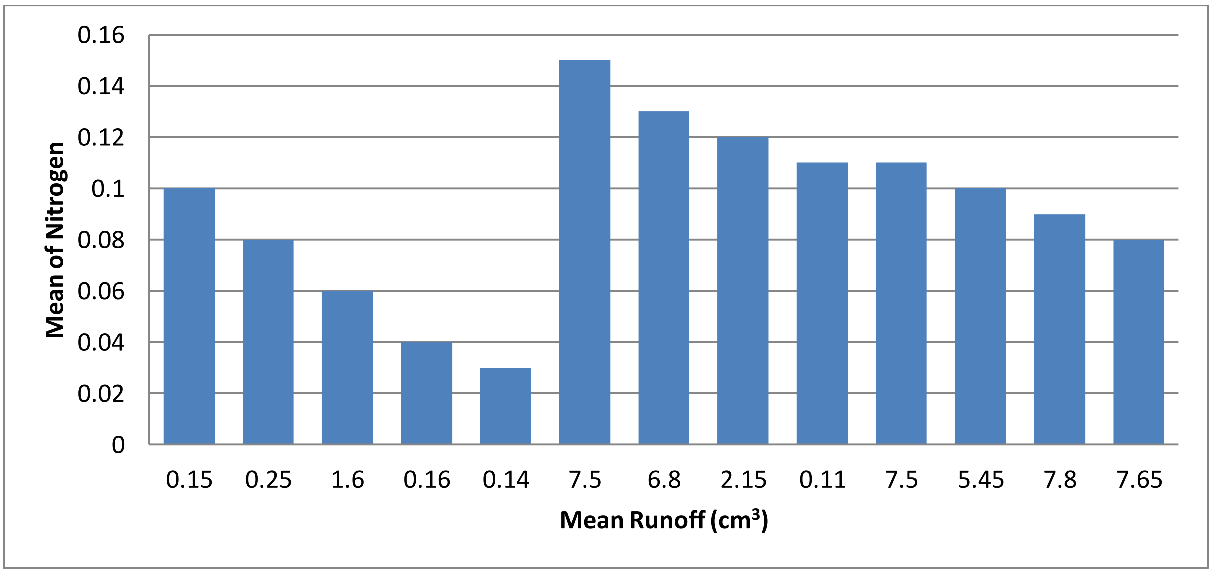

Fig. 1: Runoff against Nitrogen

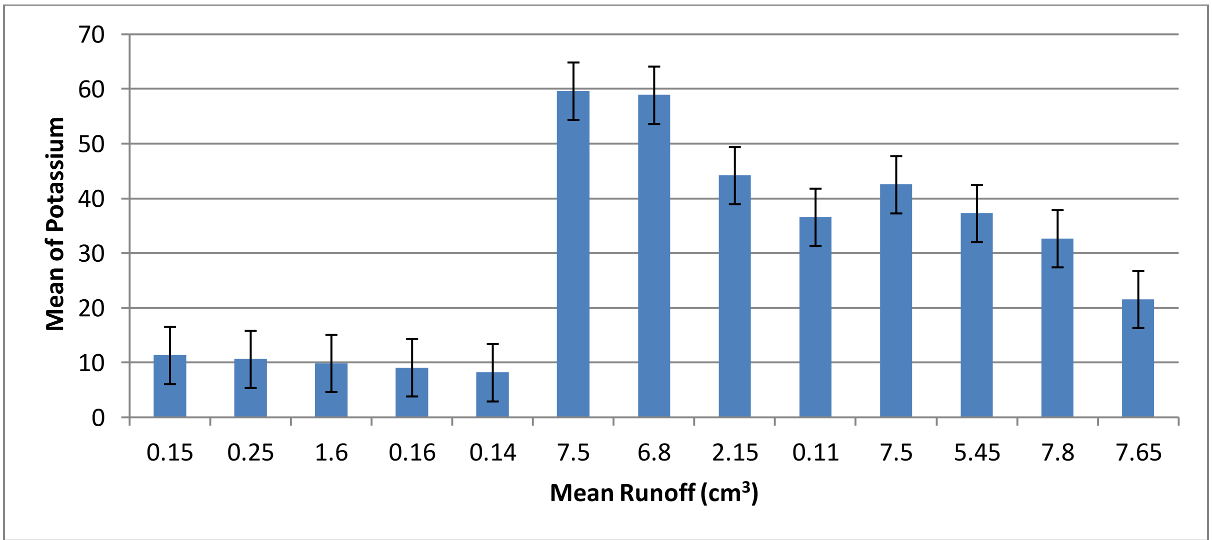

Fig. 2: Runoff against Potassium

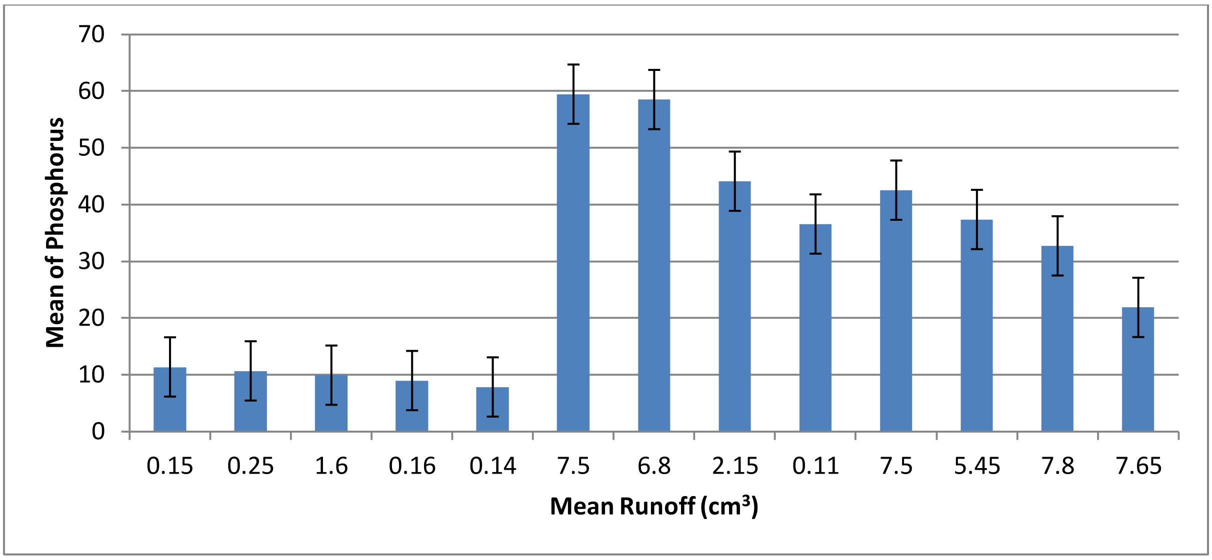

Fig. 3: Runoff against Phosphorus

IV. Conclusion

The physical processes governing soil erosion are complicated, this study simplified some case and step towards solving more complicated problems on farm runoff as related to nutrient. The study examined the relationship of farm runoff to nutrient, rainfall, vegetal cover and soil nutrient. It determines the appropriate amount of nutrient in specific quantity of farm runoff (cm^3) and the proportional amount of nutrient that will be produced by unique amount of rainfall as well as percentage of nutrient losses. The nutrients decease steadily after each rainfall and runoff thereby establishing the fact that runoff has negative effect on the nutrient properties of the soil.

This study provides a good understanding of the mechanics of farm runoff with respect to nutrients. It also demonstrates the security erosion which is a function of amount of rainfall, quantity of farm runoff, vegetal cover, the quantity of materials supplied by detachment and the capacity of eroding agent to transport it.

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Awotoye, et. al. "Water Quality Study of Farm Runoff with Respect to Nitrogen, Potassium and Phosphorus (NPK)." *IOSR Journal of Research & Method in Education (IOSR-JRME)*, 11(2), (2021): pp. 47-52.