Effect of Tillage Direction on Phosphorus Loss from Sediment Yield and Surface Runoff

*[1]Temitayo A. Ewemoje and [2]Ibrahim A. Kuti
[1]Department of Agricultural and Environmental Engineering, University of Ibadan, Nigeria
[2]Department of Agricultural & Bioresources Engineering, Federal University of Technology, Minna, Nigeria
tayo_ewemoje@yahoo.co.uk | abykuti6@futminna.edu.ng

Received: 01-DEC-2020; Reviewed: 22-DEC-2020; Accepted: 29-DEC-2020
http://dx.doi.org/10.46792/fuoyejet.v6i1.592

Abstract- This paper assessed the impact of conservation and irrational ridge on phosphorus loss along the riverbank under rainy conditions. To understand the effects, experiments were conducted on farmland with slope gradients of 2%, 3% and 5%. Treatments included groundnut, cowpea, soybean, and no crop: contour and irrational ridge alternated in each runoff block. Standard method was used to calculate phosphorus loss. The results indicated that quantity of phosphorus loss in sandy loamy soils was 4.5 times higher than in loamy sand. In contrast, the phosphorus release (runoff) in loamy sand was 13.52 times higher than in sandy loam, so the average phosphorus loss in soil and surface runoff were 0.4 and 2 Kg / ha / year, respectively. Outcomes proved that the interaction between irrational ridge and vegetation cover increased the phosphorus concentration in the soils than water, thereby reducing aquatic organisms in rivers and creasing health risks for humans. The study recommends that contour cultivation be used very well to reduce phosphorus loss from sediment and runoff.

Keywords- Contour and Irrational Tillage, Slope, Cover Crops, Analysis of covariance, Tillage Erosion, River

1 INTRODUCTION

Soil tillage is the preparation of land for crop cultivation, which can be done either manually or mechanically (Carter, 2005). Contour tillage alters the physical and chemical properties of the topsoil and distributes water within the root zone (Dotaniya et al., 2019). Numerous studies have reported that contouring reduces surface runoff by increasing infiltration of water, thereby reducing soil degradation and phosphorus loss (Dass et al., 2011; Liu et al., 2010; Gilley, 2005). When heavy rainfall interacts with land use, the storage capacity of the ridge cannot store surface-water, and the sediment bound with nutrient loss. However, intensive and continuous soil cultivation destroys the soil structure through surface sealing, causes soil degradation (Tan et al., 2015) and phosphorus loss, and transports it to the riverbanks (Blanco and Lal, 2008).

Few studies have shown that ridges along the slope, also known as traditional farming methods, cause soil degradation and loss of soil and water, which in turn leads to the accumulation of sediment yields associated with nutrients in dams (Oladosu et al., 2019; Tan et al., 2015). Among the soil nutrients, phosphorus is the main constituents (Balemi and Negisho, 2012) and its presence in the root zone usually increases crop yield and productivity. Sediment-bound nutrients cause pollution of water bodies and rivers, thereby reducing the suitability of water for human and animal consumption, as excess phosphorus is released into the river (Khatri and Tyagi, 2015; Yang et al., 2008; Gilley, 2005).

Previous study has shown that phosphorus losses of less than 1 kg/ha/ year can accelerate eutrophication (Sharpley et al., 2015). Two studies have shown that contouring efficiently reduces nutrient loss due to runoff (Guo et al., 2019, US Department of Agriculture, 2017; Xia et al., 2014), but no research has reported how contour ridges reduced phosphorus release in coarse sediments. It was also found that phosphorus loss in sediment is lower than in water (Lal and Mishra, 2015).

Studies on determination of quantity of phosphorus loss in loamy and sandy soils are rarely available and assessed the contours and irrational impacts of tillage on phosphorus release between soil types. Contour and non-rational tillage were interacted with cover plants to assess their effects on phosphorus loss as part of controlling nutrient loss, and Niger State uses about 80% of its arable land for raising crops (Ahmed and Olayide, 2017), and some farmers in prefer to grow crops on ridges along the slope because this reduces the cost of soil preparation and causes soil degradation. As a result, the extent of water pollution in the Koropa and Shatta stream/river has never been investigated. Moreover, the call for fertilizer is increasing in this region and in-directly influences Nigeria's budget allocation for fertilizer imports due to incorrect agricultural practices. However, studies on the extent / amount of phosphorus loss in non-rational ridges are rarely available. The objectives of this study were to quantify and evaluate the effects of contour and non-rational ridges under different slopes and vegetative cover on phosphorus loss.

2 MATERIALS AND METHODS

2.1 EXPERIMENTAL DESIGN AND MEASUREMENT

The study was carried out in January, 2018 on the soil of Koropa and Shatta. The soil type, infiltration rate and soil nutrients of Koropa and Shatta were determined using the standard methods. The soil of Koropa was sandy loam and soil of Shatta was loamy sand. Each plot was 5.5 m long and 2.0 m wide which was demarcated and guided by corrugated iron sheet and channeled into a storage tank of capacity 240 litres as shown in Figure 1. Levelling of the plot was carried out on each plot to a desired slope and measured using the levelling instrument. The slope was determined using Equation (1).

$$slope = \frac{hd}{d} \times 100 \qquad (1)$$

Where, hd is the elevation height (m) and d is the slope length (m)

*Corresponding Author

The experiment used mixed factorial design to arrange covers crops and contour line ridge on the runoff plots at gradients of 2%, 3% and 5% (Figure 1). Conservation and irrational tillage were cultivated to the height of 30 cm and spaced 1m apart by the use of local hoe. Rain gauge cylinders are installed above 30 cm of the earth surface, and soil was amended after three weeks of planting in 2018 due to lack of phosphorus. The experiments were performed from 2018 to 2019.

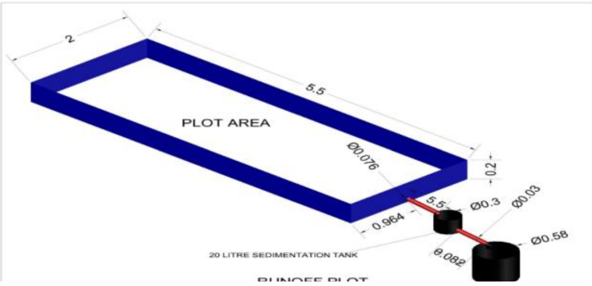


Fig. 1: Runoff plot

Sediments (coarse) removed from surface runoff in each 20L tank and added to the surface-water to the 240L reservoir before vigorous stirring. Surface-water was measured using plastic rule. One litre of water was separated from suspended sediment by decantation and dried at 105°C for 24 hours in the laboratory. The deposit (coarse) was air-dried after every rainfall event. Sediments was weighed in kilograms (Gabiri et al., 2015; Sensoy and Kara; 2014) and computed the runoff volume along with sediment yield, as shown in the equation 2 - 4 (Sensoy and Kara; 2014; Rustomji, 2008).

$$P = \frac{V(m^3)}{A\ (m^2)} \quad (2)$$

$$V = \frac{h\pi\ ((2B^2)+r^2)}{3} \quad (3)$$

$$Y\ (Kg\ ha^{-1}) = R\ (L) \times S\ (kg\ L^{-1}) \times \frac{10{,}000}{A\ (m^2)} \quad (4)$$

$$Z\ (kg\ ha^{-1}) = Y + G \quad (5)$$

V= volume of water in the tank (m^3)
A= plot size (m^2)
r=top and bottom radius of the tank (m)
B= middle radius of the tank (m)
h= height of the tank (m)
Y=suspended sediment (Kg ha^{-1})
P= depth of runoff (mm)
S= sediment concentration (kg L^{-1})
A=plot size (m^2)
Z=sediment yield (kg ha^{-1})
G=coarse sediment (kg ha^{-1})

Sediments and 1L of water sample were subjected to phosphorus analysis at the department of water resources, aquaculture and fisheries, Federal University of Technology Minna. The following procedures were used for phosphorus – 5 g of air-dried soil was weighed (2 mm) into a 250 ml plastic bottle. 35 ml of the Bray 2 extracting solution added and shook for 5 minutes. This substance filtered through Whatman No. 5 folded filter (Nos. 44). Put 5 ml aliquots into a 50 ml flask and add distilled water to increase the volume to 40 ml and add 8 ml to the ascorbic acid solution and mix until 50 ml (Okalebo et al., 2002). The absorption of the coloured solution, which is identical to the standard solution at 880 nm, was measured after 30 minutes, and 2 ml of Bray 2 extraction solution was taken and measured at 0, 1, 2, 3, 4 and 5 mg/l, adding 5 ml of distilled water to each of the standard solutions. The same procedure was repeated for runoff. The phosphorus concentration was measured with a spectrophotometer (752 UV-Visible). The following formulae were used to calculate the phosphorus lost in sediment yield and runoff, as indicated between Equation 5 and 6 (Iwara et al., 2018):

$$M = N \times Z \times 1{,}000 \quad (5)$$

$$E = \frac{F \times R}{10{,}000 \times 1{,}000} \quad (6)$$

Where
M=Phosphorus lost in sediment yield (g ha-1)
N=1 Litre of phosphorus concentration (mg kg-1)
Z= sediment yield (kg ha-1)
E= Phosphorus lost in runoff (g ha-1)
F= 1 Litre of phosphorus lost in water (mg L-1)
P= runoff volume (mm).

2.2 Location of the Study

The experiments were conducted in Paikoro along with Bosso Local Government Areas of Minna, Niger State, Nigeria. Koropa lies on Latitudes 9° 32' 03.78" N and Longitudes 6° 34 04.37" E of Minna, Nigeria. Shatta basin lies on Latitudes 9° 42' 34.75" N and Longitudes 6° 31' 17.90" E in Minna, Nigeria (Figure 2).

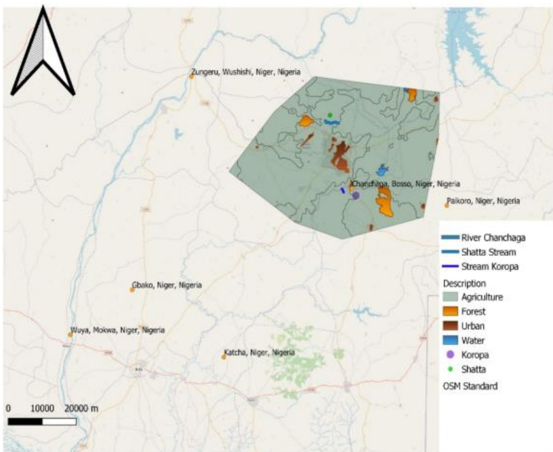


Fig. 2: Location of the study area

2.3 Data Analysis

An Analysis of Covariance (ANCOVA) is a mixture of analysis of variance (ANOVA) and linear regression (Addinsoft, 2019). ANCOVA is suitable where randomised block/mixed factorial design arranges treatments for an experiment. ANCOVA analyses phosphorus losses and the model is written as follows:

$$y_i = \beta_0 + \sum_{j=1}^{p} + \beta_j\, x_{ij} + \sum_{j=1}^{q} + \beta_{k(i,j),j} + \epsilon_i \quad (8)$$

P= number of quantitative variables,
q= number of factors,
y_i = observed values for dependent variable
x_{ij} = value taken by quantitative j for observation i,

http://dx.doi.org/10.46792/fuoyejet.v6i1.592

$K_{(i,j)}$= the index of the category of factor j for observation i,
ϵ_i = error of the model.

The phosphorus data collected fulfilled all ANCOVA assumptions. The least significant difference (LSD) was used to compare phosphorus release from both soil and water under contour and counterfeit tillage in XLSTAT software (Addinsoft, 2019). The analysis was made in 2019 XLSTAT environment.

3 Results and Discussion

3.1 Effect of Tillage Direction on Phosphorus Loss in Sediment

Table 1a shows the average phosphorus content of the soil, and the Shatta had an average phosphorus concentration of 7.7, 15.7 and 14.9 with gradients of 2%, 3% and 5%. The opposite trend was observed in Koropa (Table1a), showing that Shatta had the higher phosphorus concentration in the soil than the Koropa.

Table 1a. Phosphorus content of the soil before the experiment

Slope (%)	Location	Average Phosphorus (mg/kg)
2	Shatta	7.7
3	Shatta	15.7
5	Shatta	14.9
2	Koropa	12.0
3	Koropa	11.0
5	Koropa	9.4

Phosphorus concentration (soils) is higher in Koropa (377.629 g/ha/yr.) than in Shatta (82.909 g/ha/yr.) due to the intense irrational ridges (Table 1b). The findings agree with previous work (Sharpley et al., 2015) because total phosphorus losses in soils were less than 1 kg/ha/yr and increases eutrophication.

Table 1b. Summary of results of phosphorus loss in sediment yield (g/ha/year)

Location	Minimum	Maximum	Mean
Koropa	39.667	1025.263	377.629
Shatta	19.823	236.317	82.909

The model parameters show the phosphorus concentration (sediment) in Koropa and Shatta (Tables 2a and 2b). Outcomes prove that the ridges without crop have the greatest influence on phosphorus loss, followed by the irrational tillage (p-value =0.006 and p-value = 0.034) as shown in Table 2a. Cowpea and contour tillage have no influence on phosphorus concentration at all. Topography, groundnut and soybeans have no significant influence on the phosphorus loss (p-value>0.05).

Table 2a. Model parameters for phosphorus loss of sediment yield in Koropa (g/ha/year)

Source	Value	Standard error	t	Pr > |t|
Intercept	-127.223	201.377	-0.632	0.551
Slope	40.743	37.593	1.084	0.320
RAS	0.000	0.000		
RTS	338.927	124.455	2.723	**0.034**
Cowpea	0.000	0.000		
Groundnut	42.655	175.626	0.243	0.816
No crop	467.656	111.302	4.202	**0.006**
Soybeans	287.996	155.784	1.849	0.114

RAS is ridge across the slope; RTS is ridge along the slope

The same trend was observed in ridge along the slope, bare land with ridges, groundnut and slope were significant (P<0.05) (Table 2b). It implies that these factors have a very high effect on phosphorus release, except cowpea, contour tillage and soybean. Irrational tillage, cover crops and topography increase phosphorus loss (soil) at the Koropa and Shatta. Regan et al. (2012) reported that nutrient losses breakdown faster in loamy sand than that of sandy loam. Findings from this research showed that sandy loam breakdown faster than loamy sand and this is in line with similar study because of intensive cultivation of soil through traditional farming (Tan et al., 2015, Regan et al., 2012)

Table 2b. Model parameters for phosphorus loss of sediment yield in Shatta (g/ha/year)

Source	Value	Standard error	t	Pr > |t|
Intercept	-120.619	33.626	-3.587	0.012
Slope	28.366	8.243	3.441	**0.014**
RAS	0.000	0.000		
RTS	92.755	13.010	7.129	**0.000**
Cowpea	0.000	0.000		
Groundnut	90.458	22.128	4.088	**0.006**
No crop	106.565	18.049	5.904	**0.001**
Soybeans	53.368	24.879	2.145	0.076

RAS is ridge across the slope; RTS is ridge toward a slope

Figure 3a and 3b show the comparison of phosphorus release from soils in Koropa and Shatta. Phosphorus release found in the irrational ridge (A) differed from the opposite one (B) (Figure 3a and 3b).

http://dx.doi.org/10.46792/fuoyejet.v6i1.592 engineering.fuoye.edu.ng/journal

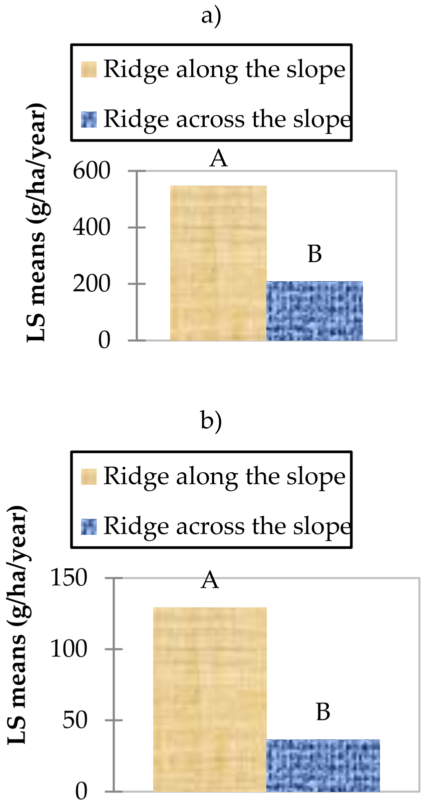


Fig. 3: Comparisons of phosphorus loss (sediment) yield in contour line ridges a) Koropa b) Shatta

In addition, phosphorus losses (soils) found in tillage without crop differ from the one in cowpea plot (Figure 4a), the same trend was noticed in the case of Shatta (Figure 4b). Ridges toward a slope coupled with cover crops had never been examined till date. However, the previous work reported that cowpea reduces soil degradation and phosphorus loss on terraced slope (Gabiri et al., 2015). Findings from this study revealed that cowpea reduced phosphorus losses in the farmland before they reached the river.

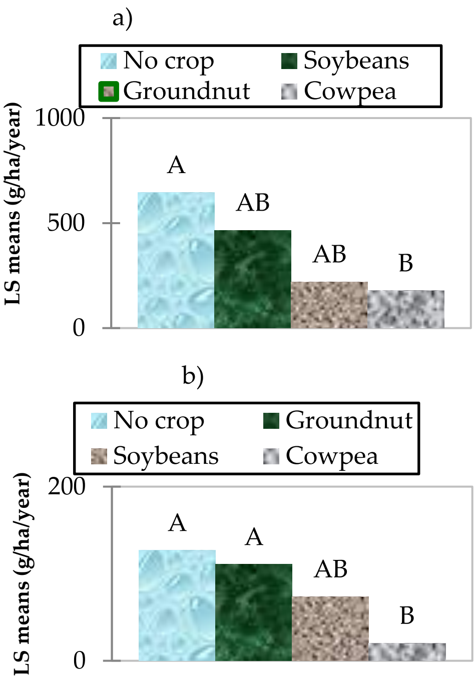


Fig. 4: Comparison of phosphorus loss (sediment yield) in cover crops a) Koropa b) Shatta

3.2 Effect of Tillage Direction on Phosphorus Loss in Surface Runoff

The average phosphorus release from runoff was higher in Koropa (2456.9 g/ha/yr.) than in Shatta (181.66 g/ha/yr.) due to intensive non-rational ridges (Table 3). This could also be due to the different phosphorus concentrations in the two sites (Table 1a). Cowpea could absorb phosphorus better than soybeans, which could reduce the phosphorus concentration in the soil sediment and the runoff. Findings from this research contradict the previous work (Sharpley et al., 2015) because the total phosphorus losses in water exceeded 2 kg/ha/yr and could increase eutrophication in river/stream.

Table 3. Summary of results of phosphorus loss of surface runoff (g/ha/year)

Location	Minimum	Maximum	Mean
Koropa	96.585	312.578	181.66
Shatta	568.404	9396.83	2456.91

The plough without a crop had a severe impact on phosphorus losses (P<0.05), while the remaining factors did not affect her concentration (Table 4a).

Table 4a. Model parameters for phosphorus loss of runoff at Koropa (g/ha/year)

Source	Value	Standard error	t	Pr > |t|
Intercept	122.976	35.134	3.500	0.013
Slope	2.964	8.600	0.345	0.742
RAS	0.000	0.000		
RTS	8.373	23.700	0.353	0.736
Cowpea	0.000	0.000		
Groundnut	-14.487	26.992	-0.537	0.611
No crop	125.454	33.242	3.774	**0.009**
Soybeans	67.507	27.724	2.435	0.051

RAS is ridge across the slope; RTS is ridge toward a slope

In Shatta, soybean, ridge without a crop, irrational tillage and topography increased phosphorus pollutants into the stream, thereby, causing water pollution and reduction in aquatics organisms (p-values <0.05) except cowpea, groundnut and contour tillage (Table 4b).

Table 4b. Model parameters for phosphorus loss of runoff at Shatta (g/ha/year)

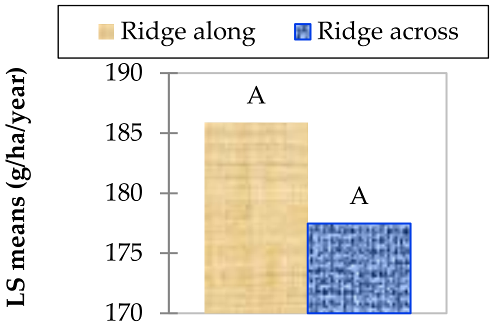
Source	Value	Standard error	t	Pr > |t|
Intercept	-3520.182	1497.549	-2.351	0.057
Slope	847.894	305.998	2.771	**0.032**
RAS	0.000	0.000		
RTS	2142.346	602.890	3.553	**0.012**
Cowpea	0.000	0.000		
Groundnut	1723.328	704.656	2.446	0.050
No crop	4648.392	1241.030	3.746	**0.010**
Soybeans	1946.682	362.518	5.370	**0.002**

RAS is ridge across the slope; RTS is ridge toward a slope

http://dx.doi.org/10.46792/fuoyejet.v6i1.592

The phosphorus loss in runoff on the contour tillage differed from down slope tillage in Shatta (Figure 5b) because of loamy sand with high pore spaces. The opposite trend was observed in Koropa (Figure 5a).

a)



b)

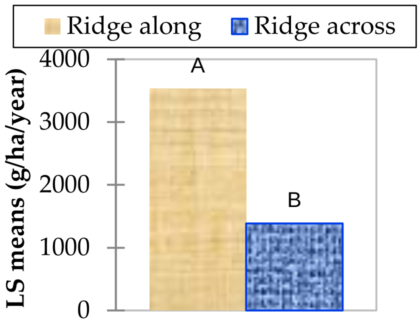
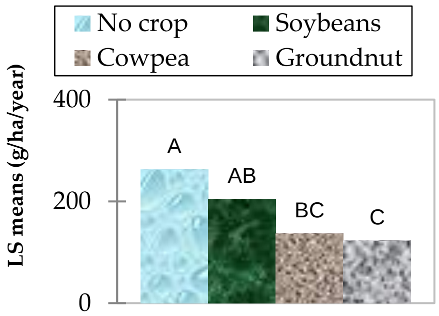


Fig. 5: Comparisons of phosphorus loss (runoff) in contour line ridges a) Koropa b) Shatta

Irrational tillage had a high impact on phosphorus release from runoff in Shatta. Phosphorus concentration got in the tillage without a crop differed from the groundnut (Figure 6a). Opposite trend noticed for cowpea plot (Figure 6b).

a)



b)

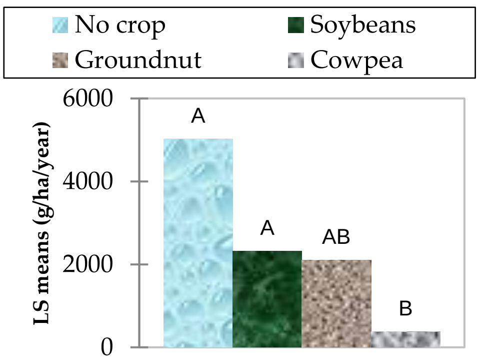


Fig. 6. Comparisons of phosphorus loss (runoff) in cover crops a) Koropa b) Shatta

Few studies revealed that groundnut and cowpea have the potential to reduce the effect of water erosion and phosphorus loss (Rashid et al., 2015, Gabiri et al., 2015). This is because groundnut and soybeans are also legumes, covering plants that can prevent erosion and absorb phosphorus from the soil to grow. The analysis observed that ridges along the slope also break organic matter faster in fine-texture soil than sandy soil. This finding is in line with previous similar studies (Regan et al., 2012) as the intensive cultivation of the topsoil caused by irrational tillage, the soils aerate, increasing the decomposition of organic matter in the soil. The study has established that the amount of phosphorus loss (soils) in sand loamy was 4.5 times the one in loamy sand (Table 1). The results of phosphorus released from loamy sand in surface runoff was 13.52 times that of phosphorus loss in sandy loam as they were under the same conditions of slope, planted the same crop type and have the same initial phosphorus content, there could be tendency that sandy loam could hold phosphorus better than the loamy sand, again, loamy sand could be more prone to water erosion than the sandy loam and that sandy loam in that area might contain more phosphorus than loamy sand.

Lal and Mishra (2015) reported that the phosphorus loss was lower in the sediment than in the water. Findings from this study are in agreement with the similar study. This nutrient (phosphorus concentration) loss carried by surface-water and sediment could possibly cause high global call for inorganic fertilizer (Gumiere et al., 2019) and posing serious impacts on the water environment (Guo et al., 2019, Khatri and Tyagi, 2015, Yang et al., 2008, Johnson and Scherer, 2010). The complex interaction between ridge across the slope and cover crops is good for reducing dynamic of land degradation in the region (Stevens et al., 2009). Results from this study agreed with the previous studies (Kisic et al., 2018, Stevens et al., 2009), they reported that ridges across the slope protected the environment from degradation. However, the one between ridges towards the slope and vegetative cover under rainfall condition still have severe effect on the phosphorus loss in soil than water. This could possibly be linked to improper agricultural practice employed by the farmers in the region (Stevens et al., 2009). The density canopy such as planting of cowpea, soybean and groundnut coupled with ridge along the slope employed by farmers in the region affected phosphorus losses severely. The surface water received very high phosphorus pollutants from both soil and water causing water pollution and reduction in fish population, because of toxic algae blooms and eutrophication (Guo et al., 2019, Khatri and Tyagi, 2015, Yang et al., 2008, Johnson and Scherer, 2010).

4 Conclusion

The effects of contour and non-rational ridges under different slopes and cover crops on phosphorus loss were assessed with the aim of quantifying and evaluating the phosphorus loss from ridges constructed across and along the slope. It was found that the average phosphorus loss in surface runoff exceeded 2 Kg/ha/yr, although the phosphorus loss (sediment) was less than 1 Kg/ha/year. This implies that intensive tillage by ridges along the slope was the main factor causing a higher phosphorus

http://dx.doi.org/10.46792/fuoyejet.v6i1.592 engineering.fuoye.edu.ng/journal

loss in sandy loam than in loamy sand. Results from this study shows that the interaction effects of ridges along the slope and cover crops have increased phosphorus loss compared to contouring which means that contour ridges with cover crops serve as best management practices that reduce phosphorus loss through surface and runoff. This study shows that the amount of phosphorus loss in the soil is lower than in water, which poses a health risk to humans. Phosphorus loss in contour and non-rational ridges is different, and the study concluded that ridge along the slope and cover crops increase the phosphorus concentration in soils than in water. Therefore, it is imperative that Niger state water authority should treats the water during the rainy season in order to avert its health effects on the people of the region.

REFERENCES

Ahmed, M. & Olayide, O. (2017) Internship Report with Niger State Value Chain Development Programme. pp 4. http://dx.doi.org/10.13140/RG.2.2.16754.35528

Addinsoft (2019) XLSTAT statistical and data analysis solution. https://www.xlstat.com

Balemi, T., & Negisho, K. (2012). Management of soil phosphorus and plant adaptation mechanisms to phosphorus stress for sustainable crop production: a review. *Journal of soil science and plant nutrition*, 12(3), 547-562. http://dx.doi.org/10.4067/S0718-95162012005000015

Blanco, H., & Lal, R. (2008). Principles of soil conservation and management (Vol. 167169). Springer, New York. Pp 109.

Carter, M. R. (2005). Conservation tillage Encyclopedia of Soils in the Environment. Ist Edition, Academic press Elsevier, USA. pp 306-311.

Dass, A., Sudhishri, S., Lenka, N. K., & Patnaik, U. S. (2011). Runoff capture through vegetative barriers and planting methodologies to reduce erosion, and improve soil moisture, fertility and crop productivity in southern Orissa, India. *Nutrient Cycling in Agroecosystems*, 89(1), 45-57. https://doi.org/10.1007/s10705-010-9375-3.

Dotaniya, M. L., Aparna, K., Dotaniya, C. K., Singh, M., & Regar, K. L. (2019). Role of soil enzymes in sustainable crop production. Enzymes in Food Biotechnology. Academic Press, pp. 569À589, 308, 307À330. https://doi.org/10.1016/B978-0-12-813280-7.00033-5

Gabiri, G., Obando, J.A., Tenywa, M.M., Majaliwa, J.G., Kizza, C.L., Zizinga, A. & Buruchara, R. (2015) Soil and nutrient losses under cultivated bush and climbing beans on terraced humid highland slopes of Southwestern Uganda. *Journal of Scientific Research and Reports*, 8(3), 1-16. https://doi.org/10.9734/JSRR/2015/18113

Gumiere, T., Rousseau, A.N., da Costa, D.P., Cassetari, A., Cotta, S.R., Andreote, F.D., ..., & Pavinato, P.S. (2019) Phosphorus source driving the soil microbial interactions and improving sugarcane development. *Scientific reports*, 9(1), 1-9. https://doi.org/10.1038/s41598-019-40910-1

Gilley, J. E. (2005). Erosion/Water-Induced. Encyclopedia of Soils in the Environment, 463–469. https://doi.org/10.1016/b0-12-348530-4/00262

Guo, S., Zhai, L., Liu, J., Liu, H., Chen, A., Wang, H., ... & Lei, Q. (2019). Cross-ridge tillage decreases nitrogen and phosphorus losses from sloping farmlands in southern hilly regions of China. *Soil and Tillage Research*, 191, 48-56. https://doi.org/10.1016/j.still.2019.03.015

Iwara, A. I., Njar, G. N., Ogundele, F. O., & Tokula, A. E. (2018). Influence of Vegetation Characteristics on Nutrient Loss in the Rainforest Belt of Agoi-Ekpo, Cross River State, Nigeria. *Journal of Applied Sciences and Environmental Management*, 22(7), 1043-1050.

Johnson, R. & Scherer, T. (2010) Drinking Water Quality: Testing and Interpreting Your Results. pp 138. Retrieved from www.ag.ndsu.edu/agcomm

Khatri, N. & Tyagi, S. (2015). Influences of natural and anthropogenic factors on surface and groundwater quality in rural and urban areas. *Frontiers in Life Science*, 8(1):23-39. https://doi.org/10.1080/21553769.2014.933716

Kisic, I., Bogunovic, I., Zgorelec, Z. & Bilandzija, D. (2018) Effects of soil erosion by water under different tillage treatments on distribution of soil chemical parameters. *Soil & Water Research*, 13: 36-43. https://doi.org/10.17221/25/2017-SWR.

Lal, M. and Mishra, S. (2015) Characterization of surface runoff, soil erosion, nutrient loss and their relationship for agricultural plots in India. *Current World Environment*, 10 (2), 593. http://dx.doi.org/10.12944/CWE.10.2.24

Liu, X. B., Zhang, X. Y., Wang, Y. X., Sui, Y. Y., Zhang, S. L., Herbert, S. J., & Ding, G. (2010). Soil degradation: a problem threatening the sustainable development of agriculture in Northeast China. *Plant, Soil and Environment*, 56(2), 87-97. https://doi.org/10.17221/155/2009-PSE

Oladosu, S. O., Ojigi, L. M., Aturuocha, V. E., Anekwe, C. O., Tanko, R., (2019). An investigative study on the volume of sediment accumulation in Tagwai dam reservoir using bathymetric and geostatistical analysis techniques. *SN Applied Sciences*, 1(5), 492, https://doi.org/10.1007/s42452-019-0393-8.

Okalebo, J.R., Gathua, K.W. & Woomer, P.L. (2002). *Laboratory methods of soil and plant analysis: a working manual*. 2nd Edition, Sacred Africa, Nairobi. pp. 43-44.

Rashid, M., Kausar, R., Alvi, S. & Sajjad, M. R. (2015) Assessment of runoff and sediment losses under different slope gradients and crop covers in semi-arid watersheds. *Soil & Environment*, 34(1), 75-81. http://www.sss-pakistan.org.

Regan, J.T., Fenton, O. & Healy, M.G. (2012). A review of phosphorus and sediment release from Irish tillage soils, the methods used to quantify losses and the current state of mitigation practice. In Biology and Environment: Proceedings of the Royal Irish Academy, March 2012, Ireland. pp. 57-183.

Rustomji, P., Zhang, X.P., Hairsine, P.B., Zhang, L. & Zhao, J. (2008) River sediment load and concentration responses to changes in hydrology and catchment management in the Loess Plateau region of China. *Water Resources Research*, 44(7): 1-17. https://doi.org/10.1029/2007WR006656

Sharpley, A.N., Bergström, L., Aronsson, H., Bechmann, M., Bolster, C.H., Borling, K., ..., & Tonderski, K.S. (2015). Future agriculture with minimised phosphorus losses to waters: Research needs and direction. Ambio, 44(2), 163-179. https://doi.org/10.1007/s13280-014-0612-x

Sensoy, H. & Kara, O. (2014) Slope shape effect on runoff and soil erosion under natural rainfall conditions. *iForest-Biogeosciences and Forestry*, 7(2): 110. https://doi.org/10.3832/ifor0845-007

Stevens, C. J.; Quinton, J. N.; Bailey, A. P.; Deasy, C.; Silgram, M. and Jackson, D. R. (2009). The effects of minimal tillage, contour cultivation and in-field vegetative barriers on soil erosion and phosphorus loss. *Soil and Tillage Research*, 106(1), 145–151. https://doi.org/10.1016/j.still.2009.04.009.

Tan, C., Cao, X. Yuan, S., Wang, W., Feng, Y. and Qiao, B. (2015) Effects of long-term conservation tillage on soil nutrients in sloping fields in regions characterised by water and wind erosion. Scientific reports, 5, 17592. https://doi.org/10.1038/srep17592

U.S. Department of Agriculture, Natural Resources Conservation Service (2017). Effects of conservation practices on phosphorus loss from farm fields. Retrived from http://www.nrcs.usda. pp 100.

Xia, L., Liu, G., Ma, L., Yang, L., & Li, Y. (2014). The effects of contour hedges and reduced tillage with ridge furrow cultivation on nitrogen and phosphorus losses from sloping arable land. *Journal of soils and sediments*, 14(3), 462-470. https://doi.org/10.1007/s11368-013-0824-x.

Yang, X.E., Wu, X., Hao, H.L. and He, Z.L. (2008) Mechanisms and assessment of water eutrophication. *Journal of Zhejiang University Science B*, 9(3), 197-209. https://doi.org/10.1631/jzus.B0710626