Environment and Natural Resources Research; Vol. 12, No. 2; 2022
ISSN 1927-0488 E-ISSN 1927-0496
Published by Canadian Center of Science and Education

Physicochemical Analysis of Parameters Influencing Soil Loss for a Selected Location in North Central Nigeria Using Rainfall Simulator

John Jiya. Musa[1], Otuaro, Ebierin Akpoebidimiyen[2], Pius Olusegun Olufemi Dada[3], Eze, Peter Chukwu[4] & Jamil dams-Suberu[5]

[1]Department of Agricultural and Bioresources Engineering, Federal University of Technology, P. M. B. 65, Minna, Nigeria

[2]Department of Civil Engineering, Maritime University, Okeremkoko, Nigeria

[3]Department of Agricultural and Bioresources Engineering, Federal University of Agriculture, P. M. B. 2240, Abeokuta, Nigeria

[4]Department of Soil and Land Management, Federal University of Technology, Minna, Nigeria

[5]Lower Niger River Basin Development Authority, P. M. B. 1529, Ilorin, Nigeria

Correspondence: John Jiya. Musa, Department of Agricultural and Bioresources Engineering, Federal University of Technology, P. M. B. 65, Minna, Nigeria. E-mail: johnmusa@futminna.edu.ng

Received: October 20, 2021 Accepted: December 11, 2022 Online Published: August 2, 2022

doi:10.5539/enrr.v12n2p14 URL: https://doi.org/10.5539/enrr.v12n2p14

Abstract

Developing a simple and proper model that can accurately predict runoff generation for various locations is in strong demand. This study developed a simple model based on the interactive effects of rainfall intensity and soil physicochemical properties on runoff using a locally produced rainfall simulator. The drop velocity (DV) was calculated to be 8.101m/s and 2.443 m/s when operated at maximum and minimum intensity, respectively, and the performance test revealed the experimental coefficient of uniformity (CU) and rainfall intensity from the simulator to be 79.86 % at 31.79 $mmhr^{-1}$ and 78.03 % at 16.08 $mmhr^{-1}$ at maximum and minimum intensity respectively. Results showed that the soils were loamy sand, with clay having the lowest percentage between 3.55% - 4% and sand having the highest percentage between 78.4% - 80.1% on both plots. Runoff significantly correlated with pH(H_20), nitrogen and rainfall intensity for vegetative plot ($p < 0.001$, $R^2 = 86.29\%$) while for bare plot, runoff significantly correlated with pH (KCl), Electrical Conductivity, Exchangeable Calcium, and rainfall intensity ($p < 0.001$, $R^2 = 92.39\%$). This result revealed that rainfall intensity and alkalinity are key factors influencing runoff in the study location.

Keywords: bare, drop velocity, physicochemical, soil, vegetative

1. Introduction

The variety of organisms that can survive in soil depends on the water available (Greg and Percy, 2005). Thus, for cell survival, nutrients must be available to them in which water acts as a means of nutrient transport, and the amount of soil moisture also depends on the climate, soil type and amount of humus in that soil (Gundersen *et al.*, 2010).

Nutrient dynamics are a significant factor in understanding the ecological status and ecosystem functioning (Ekanade, 1990). Thus, maintaining good soil quality through a continuous mix of litter components and synergistic interactions encourages mixed cropping for maximum agricultural produce (Ekanade, 1990). On the other hand, the Physico-chemical properties of soil affect when soil properties deteriorate with time leading to soil nutrients leaching from the soil because of changes in land use, especially from forest to arable land (Oguike and Mbagwu, 2009). Thus, as cultivation continues, the declining trend of soil productivity and the physical properties of soils commonly continue because of the decrease in soil pH and organic matter content (Oguike and Mbagwu, 2009).

Runoff generation is a significant player in soil loss (Le Bissonnais *et al.,* 2005) and nutrient movement from the soil surface (Lal, 1998; Simard *et al.,* 2000; Ng Kee Kwong *et al.,* 2002). However, the runoff generation process is a complex and nonlinear phenomenon that involves different mechanisms, making it difficult to model (Vaezi *et al.,* 2010). Thus, Lin and Wang (2007) said the need for a correct and easily used model for proper runoff generation is strongly demanded. Schwab *et al.* (1993) classified the factors affecting runoff into those associated with the rainfall, such as rainfall duration and intensity, and those with watersheds, such as soil, slope, shape, and surface storage. Thus, soil properties play a significant role in deciding the runoff generation behaviour (Vaezi *et al.* 2010).

Recent research has shown that soil surface structure is one of the critical factors of the watershed, controlling runoff and later water erosion in farmlands (Le Bissonnais *et al.,* 2005). Thus, it affects infiltration rates and runoff generation, making it a threat to sustainable agriculture. (Auzet *et al.,* 2004). Furthermore, Adekalu *et al.* (2007) said that coarse particles of soils play an essential role in declining surface runoff. As well as the addition of organic matter to the soil results in an increase in soil water infiltration capacity leading to low surface runoff (Zehetner and Miller, 2006; Zeiger and Fohrer, 2009).

The first step in modelling runoff involves knowing the possible factors that control runoff (Schwab *et al.,* 1993). Thus, several aspects are necessarily neglected in these methods of runoff, making assumptions simple about the influence of the others. As a result, different models were developed to simulate the runoff generation process, broadly categorised as a conceptual, empirical black box and physically-based distributed models (Vaezi *et al.,* 2010). Thus, each of these models has advantages and limitations (ASCE, 2000b).

This study aims to analyse the extent to which soil physicochemical properties influence runoff generation and develop an empirical model for predicting runoff in Ilorin using a locally designed rainfall simulator.

2. Materials and Methods

2.1 Study Site Description

The study site was within the Lower Niger River Basin Development Authority, Ilorin, Kwara State, Nigeria. The location is 324m above sea level, with coordinates latitude 8°30'31" N and longitude 4°35'53" E (Fig 1). Ilorin climate exhibits wet and dry seasons with an average annual precipitation of 1200mm, indicating more spatially and temporary variability with atmospheric temperature ranging from 33 and 35°C between November and January and 34 to 37°C between February and February April (Ajadi *et al.*, 2011). Thus, sunlight lasts about 6.5 to 7.7 hours daily from November to May. The study area was strategically selected based on the guidelines by Wallingford (1996). The soils in these areas are made of loamy soil with a low and medium level of fertility (Ajibade and Ojelola, 2004), with significant soil types to constitute lateritic soil because of the leaching of minerals and nutrients because of the elevated temperature coupled with high seasonal rainfall of the area.

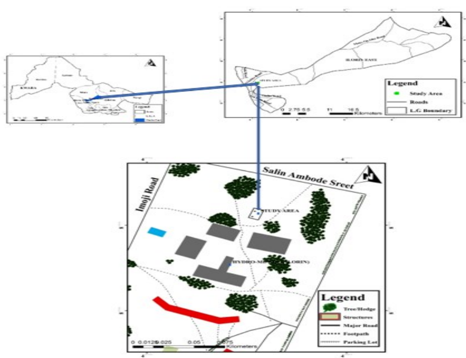

Figure 1. Map of Study Location

2.2 Rainfall Simulator Characteristics

For this study, a 2.2 m x 2 m rainfall simulator was designed, fabricated, and calibrated, mounted on a wooden frame of 2 m x 2 m. The wood size was 0.0508m x 0.0508 m hardwood with a length and breadth of 2m and 1.65 m of height with each of its legs buried, 0.3 m into the ground to stand firmly. The rainfall simulator had a main-pipe connection that received water from the pump and supplied the laterals. These laterals, in turn, distribute water to the sub-lateral, where the water is sprayed through the shower roses. Each shower rose was 90 mm in diameter, made up of 105 holes, and each of the holes had an approximate diameter of 2 mm, as presented in Figure

2. The drop velocity (DV) was calculated to be 8.101 ms^{-1} and 2.443 ms^{-1} when run at maximum and minimum intensity, respectively. The performance test revealed the experimental coefficient of uniformity (CU) and rainfall intensity from the simulator to be 79.86 % at 31.79 $mmhr^{-1}$. and 78.03 % at 16.08 $mmhr^{-1}$. when running maximum-minimum intensity, respectively. Table 1 presents the characteristics of the rainfall simulator at both minimum and maximum intensity.

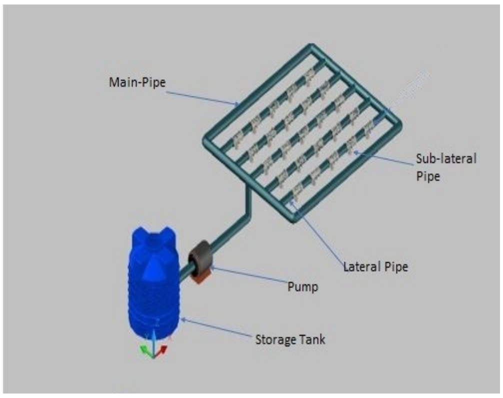

Figure 2. 3D View of the Rainfall Simulator

Table 1. Characteristics of the Rain Simulator at Both Maximum and Minimum Intensity

Flow rate	Maximum Intensity	Minimum Intensity
Coefficient of Uniformity CU (%)	79.86	78.03
Standard Deviation	0.82	0.44
Area (m^2)	4	4
Average Intensity ($mmhr^{-1}$)	31.79	16.08
Kinetic Energy ($Jm^{-2}mm$)	26.07	22.23
Erosivity Index R (MJ mm ha^{-1} h^{-1})	1278.63	543.46

2.3 Experimental Runoff Plots

The two treatments of disturbed and undisturbed soils were left to fallow for a year before the experiment was conducted. Galvanised iron sheets of approximately 30 cm in height were driven 10cm into the soil to transport runoff into the runoff collection system, thus handling the interactions' complexity and minimising disturbance Sadeghi *et al.* (2011). For optimal lengths for estimation of sediment and runoff parameters based on the adequate coverage of the rainfall simulator, the size 2m by 1m was adopted for each plot. The runoff collection systems consisted of a fabricated iron ground frame buried into the ground and a 60-Litre sized tank installed at the lower part of each plot. This is in line with the works of Sadeghi *et al.* (2011). The average slope of plot A with vegetation was 0.296%, while the average slope of plot B with bare soil was 0.03% Plot A.

2.4 Field Study

The pumping machine of the rainfall simulator was powered on, and the rainfall simulator supplied water to the experimental plots for 10 minutes (Yusuf *et al.,* 2016). The pumping process was conducted to calibrate the minimum and maximum rainfall intensity based on the rainfall simulator. The soil samples were collected after each simulation according to Vaezi *et al*. (2010) guidelines. The total runoff volume collected in the tank was measured and recorded. The bulked samples were appropriately labelled and kept in the refrigerator to minimise further chemical and physical changes in the sediment and water before being taken to the laboratory for further analysis and recorded against each plot (Wudneh, 2012). A complete block design (CBD) was adopted to design the soil estimation experiment with no replication in each block. (Egharevba and Ibrahim, 2006). Factors considered for this experiment were runoff, rainfall, and rainfall intensity with soil loss as the first response and data were analysed using Microsoft Excel and Minitab Statistics tool.

3. Results

The correlation matrix results of runoff and physicochemical properties for vegetative and bare soils are presented in Tables 2 and 3. Figures 3 and 4 show that the soil from the study area is loamy sand, as Obaid (2016), with clay having the lowest percentage between 3.55 - 4% and sand having the highest percentage between 78.4 - 80.1% for vegetative plots and bare plot, respectively.

Table 2. The Correlation Coefficient of Runoff and Physicochemical Properties of Soils for the Vegetative Plot

	$pH(H_20)$	pH (KCl)	OC	OM	EC	Sand %	Silt %	Clay %	ExC	ExM	ExA	N	P	ExP	S	MC	I	R
pH(H20)	1																	
pH (KCl)	0.91	1																
OC	-0.76	-0.78	1															
OM	-0.76	-0.78	1	1														
EC	0.75	0.76	-0.83	-0.83	1													
% Sand	0.19	0.38	-0.33	-0.33	0.12	1												
% Silt	-0.46	-0.62	0.48	0.48	-0.34	-0.41	1											
%Clay	B	B	B	B	B	B	B	1										
ExC	-0.61	-0.58	0.68	0.68	-0.83	-0.01	0.1	B	1									
ExM	-0.06	-0.12	0.11	0.11	0.24	-0.27	0.42	B	-0.35	1								
ExA	-0.62	-0.6	0.45	0.45	-0.74	-0.04	0.22	B	0.86	-0.33	1							
N	-0.78	-0.81	0.85	0.85	-0.77	-0.32	0.61	B	0.71	0.29	0.67	1						
P	-0.72	-0.74	0.82	0.82	-0.81	-0.28	0.45	B	0.6	0.13	0.44	0.75	1					
ExP	-0.41	-0.39	0.05	0.05	-0.46	0.02	0.16	B	0.54	-0.37	0.87	0.36	0.21	1				
S	-0.75	-0.75	0.91	0.91	-0.93	-0.22	0.37	B	0.82	-0.1	0.61	0.81	0.92	0.27	1			
MC	0.56	0.61	-0.68	-0.68	0.72	0.16	-0.44	B	-0.49	0.24	-0.55	-0.58	-0.39	-0.3	-0.59	1		
I	0.77	0.79	-0.97	-0.97	0.84	0.34	-0.56	B	-0.66	-0.15	-0.48	-0.89	-0.87	-0.11	-0.93	0.66	1	
R	.692**	.544*	-.494*	-.502*	.605**	-0.118	-0.038	B	-.827**	0.084	-.751**	-.602**	-0.44	-.540*	-.577**	0.229	.451*	1

** is the Correlation is significant at the 0.01 level (2-tailed); * is the Correlation is significant at the 0.05 level (2-tailed); b is the Cannot be computed because at least one of the variables is constant; OC is the Organic Carbon (%); OM is the Organic Matter (%); EC is the Electrical conductivity (uS/cm); ExC is the Exchangeable Calcium (mMol/100g); ExMag is the Exchangeable Magnesium (mMol/100g); ExA is the Exchangeable Acidity (mMol/100g); N is the Total Nitrogen (%); P is the Available Phosphorus (ppm); ExP is the Exchangeable Potassium (mMol/100g); S is the Available Sulphur (ppm); MC is the Moisture Content (%); I is the Rainfall Intensity (mm/hr), and R is the Runoff Volume (m^3).

Table 3. The Correlation Coefficient of Runoff and Physicochemical Properties of Soil for a Bare Plot

	pH(H20)	pH (KCl)	OC	OM	EC	Sand%	Silt%	Clay%	ExC	ExM	ExA	N	P	ExP	S	MC	I	R
pH(H20)	1																	
pH (KCl)	0.35	1																
OC	-0.23	-0.14	1															
OM	-0.23	-0.14	1	1														
EC	-0.08	0.48	-0.24	-0.24	1													
% Sand	0.23	0.55	-0.67	-0.67	0.75	1												
% Silt	-0.1	-0.43	0.58	0.58	-0.74	-0.86	1											
%Clay	-0.23	-0.49	0.73	0.73	-0.66	-0.94	0.77	1										
ExC	-0.04	-0.24	0.84	0.84	-0.25	-0.58	0.66	0.57	1									
ExM	0.1	-0.07	0.34	0.34	-0.08	-0.15	0.15	0.25	0.4	1								
ExA	-0.21	-0.6	0.44	0.44	-0.69	-0.84	0.64	0.73	0.33	-0.27	1							
N	-0.53	-0.37	0.81	0.81	-0.43	-0.78	0.61	0.8	0.58	0.15	0.62	1						
P	-0.39	-0.45	0.12	0.12	-0.55	-0.55	0.27	0.56	-0.23	-0.23	0.67	0.58	1					
ExP	0.25	-0.64	0.41	0.41	-0.75	-0.75	0.72	0.74	0.51	0.17	0.71	0.38	0.34	1				
S	-0.16	-0.6	0.71	0.71	-0.71	-0.91	0.8	0.91	0.64	0.09	0.83	0.82	0.56	0.84	1			
MC	0.33	0.34	-0.72	-0.72	0.47	0.83	-0.66	-0.7	-0.62	0.01	-0.77	-0.78	-0.39	-0.44	-0.74	1		
I	0.28	0.56	-0.81	-0.81	0.64	0.93	-0.79	-0.9	-0.71	-0.17	-0.82	-0.89	-0.52	-0.73	-0.97	0.84	1	
R	-0.31	.550*	-0.25	-0.25	.696**	.613**	-.668**	-.615**	-.468*	-0.37	-0.4	-0.24	-0.08	-.859**	-.600**	0.29	.495*	1

** is the Correlation is significant at the 0.01 level (2-tailed); * is the Correlation is significant at the 0.05 level (2-tailed); b is the Cannot be computed because at least one of the variables is constant; OC is the Organic Carbon (%); OM is the Organic Matter (%); EC is the Electrical conductivity (uS/cm); ExC is the Exchangeable Calcium (mMol/100g); ExMag is the Exchangeable Magnesium (mMol/100g); ExA is the Exchangeable Acidity (mMol/100g); N is the Total Nitrogen (%); P is the Available Phosphorus (ppm); ExP is the Exchangeable Potassium (mMol/100g); S is the Available Sulphur (ppm); MC is the Moisture Content (%); I is the Rainfall Intensity (mm/hr), and R is the Runoff Volume (m^3).

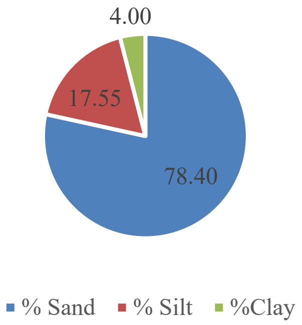

Figure 3. Average soil particle (vegetative plot)

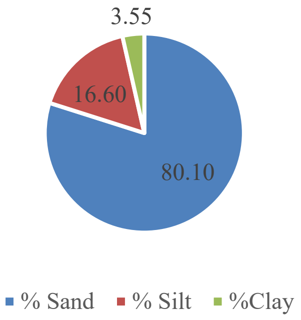

Figure 4. Average soil particle (bare plot)

Please give the introduction to equations 1 and 2. You will also need to discuss the four equations briefly. This is urgent.

Equations 1 and 2 shows the regression analysis of the relationship between runoff (R) and physico-chemical properties and rainfall intensity (I) of both the vegetative and bare plot of which both showed high coefficient of determination (R^2) of 86.29% and 92.39% respectively. Equations 1 and 2 was further optimized into Equations 3 and 4 respectively. For Vegetative Plot.

$$R = 0.235156 + 0.0307152\, pH(H_20) - 0.00791598\, pH(KCL) - 0.052688\, OC + 0.0339638\, EC - 0.0504426\, ExC + 0.0327179\, ExA - 0.845677\, N - 0.00233846\, ExP - 0.00145079\, S - 0.00402913\, I \quad 1$$

($p < 0.001$, $R^2 = 86.29\%$)

For Bare Plot.

$$\mathrm{R} = -0.246455 + 0.0773836\,\mathrm{pH(KCl)} + 0.173068\,\mathrm{EC} + 0.00525841\,\%\,\mathrm{Sand} + 0.00217344\,\%\mathrm{Silt} - 0.0242544\,\%\mathrm{Clay} - 0.0787939\,\mathrm{ExC} - 0.911683\,\mathrm{N}\,(\%) - 0.482842\,\mathrm{Ex\,P} + 0.00370143\mathrm{S} - 0.00880041\,\mathrm{I}$$

$$R = -0.246455 + 0.0773836\, pH(KCl) + 0.173068\, EC + 0.00525841\, \%\, Sand + 0.00217344\, \%Silt - 0.0242544\, \%Clay - 0.0787939\, ExC - 0.911683\, N\,(\%) - 0.482842\, Ex\,P + 0.00370143S - 0.00880041\, I \quad 2$$

($p < 0.001$, $R^2 = 92.39\%$

Equations 3 and 4 stand for the new empirical model extracted from multiple regression analysis between runoff as response and its existing physicochemical properties and rainfall intensity as factors from the vegetative and bare plots.

For Vegetative Plot:

$$R = 0.235156 + 0.0307152\, pH(H_20) - 0.845677\, N - 0.00402913\, I \quad 3$$

($p < 0.001$, R2 = 86.29%)

For Bare Plot:

$$R = -0.246455 + 0.0773836\, pH(KCl) + 0.173068\, EC + 0.0787939\, ExC - 0.00880041\, I \quad 4$$

($p < 0.001$, $R^2 = 92.39\%$)

3. Discussion

The results showed that the runoff volume significantly correlated with pH(H_2O) (p<0.01), pH(KCL) (p<0.05), Organic Carbon (p<0.05), organic matter (p<0.05), Electrical Conductivity (p<0.05), Exchangeable Calcium (p<0.01), Exchangeable Acidity (p<0.01), Total Nitrogen (p<0.01), Exchangeable Potassium (p<0.05), Available Sulphur (p<0.01) and rainfall intensity (p<0.05) while its relationship with the percentage of Sand and Silt in the soil, Exchangeable Magnesium, Available Phosphorus were found to be insignificant, percentage of clay was not computed because it was constant. From the bare plot, runoff volume significantly correlated with pH(KCL)(p<0.01), Electrical conductivity (p<0.05), Percentage of Sand, Silt and Clay (p<0.05), Exchangeable Calcium (p<0.05), Exchangeable Potassium (p<0.01), Available Sulphur (p<0.05) and Rainfall Intensity (p<0.05) while its relationship with pH(H_20), Organic carbon, Organic matter, Exchangeable Magnesium, Exchangeable Acidity, Total Nitrogen, Phosphorus and moisture content were insignificant.

It was seen that more of the soil physicochemical properties positively influenced runoff in the study area. From equation 3, pH (H_2O), Electrical conductivity and Exchangeable Acidity positively influenced runoff; this may be due to increased alkalinity from the earlier leaching. As soil organic and inorganic particles were washed away through the runoff process, soil alkalinity increased, increasing soil ph. This was seen as a change in the clay content compared with the bare plot at maximum rainfall intensity. This reduction indicates soil loss, which may explain the positive relationship influence of runoff by pH (KCL), Electrical conductivity and Exchangeable potassium in equation 4. Griss *et al.* (2009) confirmed a correlation between electrical conductivity and Cation Exchange Capacity CED through its relationship to clay. Exchangeable calcium from the vegetated plot negatively influenced the runoff at a minimum and maximum intensities. Pepper and Morrissey (1985) confirmed that runoff negatively affects the exchangeable calcium percentage.

Rainfall intensity had a negative relationship with runoff from vegetative and bare plots, as seen in equations 3 and 4. This may be due to the nature of the soil (loamy sand) in which there is low organic matter and high infiltration and other factors such as aggregate stability. Earlier research by Barthes and Roose (2002) said that soil aggregates become stable, thus influencing soil susceptibility to water erosion, but Arnaez *et al.* (2007) did observe that multiple variables such as rainfall intensity, kinetic energy and runoff could explain more variance of soil losses than a single variable, such as rainfall intensity. Soil organic matter is recognised as an outstanding binding and bridging agent in enhancing infiltration capacity, soil's structural stability, and reducing runoff (Hartanto *et al.,* 2003; Fernandez *et al.,* 2006; Zhang *et al.,* 2007).

4. Conclusion

In the planning and design of hydraulic structures, the first step must be the modelling of runoff, in which limited studies show the relationship between the physicochemical properties of the soil and runoff in the study area. Therefore, the research was conducted in a selected location in North Central Nigeria, using a locally fabricated rainfall simulator to decide the interactive effect between rainfall intensity and soil physicochemical properties, affecting runoff and modelling their relationship based on easily measurable soil properties. As a result, it was concluded from the physicochemical analysis that rainfall intensity, soil pH and alkalinity are the three key factors influencing runoff in the study area.

References

Adekalu, K. O., Olorunfemi, I. A., & Osunbitan, J. A. (2007). Grass mulching effect on infiltration, surface runoff and soil loss of three agricultural soils in Nigeria. *Bioresource Technology, 98*, 912-917. https://doi.org/10.1016/j.biortech.2006.02.044

Ajadi, B. S., & Adeniyi Adedapo, A. M. T. (2011). Impact of Climate Change on Agriculture and Food Security. *Global Journal of Human Social Science, 8*(3), 780-782.

Ajibade, L. T., & Ojelola, A. O. (2004). Effects of Automobile Mechanics Activities on Soils in Ilorin, Nigeria. *Geo-Studies Forum, an International Journal of Environmental and Policy Issues, 2*, 18-27.

Arnaez, J., Lasanta, T., Ruiz-Flaño, P., & Ortigosa, L. (2007). Factors affecting runoff and erosion under simulated rainfall in Mediterranean vineyards. *Soil and Tillage Research, 93*(2), 324-334. https://doi.org/10.1016/j.still.2006.05.013

ASCE (2000b). Task Committee on Application of Artificial Neural Networks in Hydrology: Artificial neural networks in hydrology II: hydrologic applications, *J. Hydrol. Engng, ASCE, 5*(2), 124-137. https://doi.org/10.1061/(ASCE)1084-0699(2000)5:2(124)

Auzet, A. V., Poesen, J., & Valentin, C. (2004). Soil surface characteristics: dynamics and impact on soil erosion. *Earth Surface Processes and Landforms, 9*(29), 1063-1064. https://doi.org/10.1002/esp.1101

Barthes, B., & Roose, E. (2002). Aggregate stability as an indicator of soil susceptibility to runoff and erosion; validation at several levels. *Catena, 47*, 133-149. https://doi.org/10.1016/S0341-8162(01)00180-1

Egharevba, N. A., & Ibrahim, H. (2006). Prediction of sediment yield in runoff from agricultural land in the Southern Guinea Savanna Zone of Nigeria. *West African Journal of Applied Ecology, 10*(1), 131-138. https://doi.org/10.4314/wajae.v10i1.45709

Ekanade, O. (1990). An evaluation of soil productivity in inter-planted cocoa and kola environmental systems in Southwestern Nigeria. *Int. J. Environ. Stud., 35*, 253-259. https://doi.org/10.1080/00207239008710573

Fernández, C., Vega, J. A., Fonturbel, T., Pérez-Gorostiaga, P., Jiménez, E., & Pérez, J. R. (2006). Runoff and soil erosion after rainfall simulations in burned soils. *Forest Ecology and Management*, (234), S191.

Greg, R., & Percy, W. (2005). *Soil Biology Basics*. Retrieved 03 December, 2019 from http://www.dpi.nsw.gov.au/data/assets/pdf_file/0017/41642/Soil_bacteria.pdf.

Grisso, R. B., Mark Alley, W, G., David, Ho., & Wade, T. (2009). *Precision Farming Tools: Soil Electrical Conductivity*. Virginia Cooperative Extension Publication 442-508

Gundersen, P., Laurén, A., Finér, L., Ring, E., Koivusalo, H., Sætersdal, M., Weslien, J. O., Sigurdsson, B. D., Högbom, L., Laine, J., & Hansen, K. (2010). Environmental services provided from riparian forests in the Nordic countries. *Ambio*, *39*(8), 555-566. https://doi.org/10.1007/s13280-010-0073-9

Hartanto, H., Prabhu, R., Widayat, A. S., & Asdak, C. (2003). Factors affecting runoff and soil erosion: plot-level soil loss monitoring for assessing the sustainability of forest management. *Forest Ecology and Management, 180*(1-3), 361-374. https://doi.org/10.1016/S0378-1127(02)00656-4

Lal, R. (1998). Soil erosion impact on agronomic productivity and environmental quality, *Crit. Rev. Plant Sci., 17*, 319-464. https://doi.org/10.1080/07352689891304249

Le Bissonnais, Y., Daroussin, J., Jamagne, M., Lambert, J. J., Le Bas, C., King, D., Cerdan, O., L´eonard, J., Bresson, L. M., & Jones, R. J. A. (2005). Pan-European soil crusting and erodibility assessment from the European soil geographical database using pedo transfer rules. *Adv. Environ. Monitor. Model, 12*, 1-15.

Lin, G. F., & Wang, C. M. (2007). A nonlinear rainfall-runoff model embedded with an automated calibration method-Part 1: The model. *J. Hydrol, 341*, 186-195. https://doi.org/10.1016/j.jhydrol.2007.05.009

Ng Kee Kwong, K. F.., Bholah, A., Volcy, L., & Pynee, K. (2002). Nitrogen and phosphorus transport by surface runoff from a silty clay loam soil under sugarcane in the humid tropical environment of Mauritius, *Agriculture, Ecosystems and Environment, 91*, 147-157. https://doi.org/10.1016/S0167-8809(01)00237-7

Obaid, H. A., Shamsuddin, S., Basim, K. N., & Shreeshivadasan, C. (2014). Modelling sewer overflow of a city with a large floating population. *Hydrology: Current Research*, *5,* 171. https://doi.org/10.4172/2157-7587.1000171

Oguike, P. C., & Mbagwu, J. S. C. (2009). Variations in some physical properties and organic matter content of soils of coastal plain sand under different land use types. *World J. Agric. Sci., 5*(1), 63-69.

Pepper, R. G., & Morrissey, J. G. (1985). Soil properties affecting runoff. *Journal of Hydrology, 79*(3-4), 301-310. https://doi.org/10.1016/0022-1694(85)90060-5

Sadeghi, S. H. R., Seghaleh, M. B., & Rangavar, A. S. (2011). Plot sizes dependency of runoff and sediment yield estimates from a small watershed. *Catena, 102,* 55-61. https://doi.org/10.1016/j.catena.2011.01.003

Schwab, G. O., Fangmeier, D. D., Elliot, W. J., & Frevert, R. K. (1993). *Soil and water conservation engineering*. John Wiley & Sons, Inc., New York.

Simard, R. R., Beauchemin, S., & Haygarth, P. M. (2000). Potential for preferential pathways of phosphorus transport, *J. Environ. Qual., 29*, 97-104. https://doi.org/10.2134/jeq2000.00472425002900010012x

Vaezi, A. R., Bahrami, H. A., Sadeghi, S. H. R., & Mahdian, M. H. (2010). Modelling relationship between runoff and soil properties in dry-farming lands, NW Iran. *Hydrology and Earth System Sciences (HESS), 7*, 2577-2607. https://doi.org/10.5194/hessd-7-2577-2010

Yusuf, K. O., Oyebode, O. O., Olaoke, S. O., Omokore, S., Iwayemi, A.K., A., & Adewoye, W. A. (2017). Design and Construction of a Simple Rainfall Simulator from Locally Available Materials. *Nigerian Journal Of Pure and Applied Sciences, 30*(1), 2934-2946. https://doi.org/http://dx.doi.org/10.19240/njpas.2016.A30 Design

Zehetner, F., & Miller, W. P. (2006). Erodibility and runoff-infiltration characteristics of volcanic ash soils along an altitudinal climosequence in the Ecuadorian Andes, *Catena, 65*, 201-213, 25. https://doi.org/10.1016/j.catena.2005.10.003

Zeiger, M., & Fohrer, N. (2009). Impact of organic farming systems on runoff formation processes-A long-term sequential rainfall experiment. *Soil Till. Res., 102*, 45-54. https://doi.org/10.1016/j.still.2008.07.024

Zhang, H., Wei, J., Yang, Q., Baartman, J. E., Gai, L., Yang, X., Li, S., Yu, J., Ritsema, C. J., & Geissen, V. (2007). An improved method for calculating slope length (λ) and the LS parameters of the Revised Universal Soil Loss Equation for large watersheds. *Geoderma, 308*, 36-45. https://doi.org/10.1016/j.geoderma.2017.08.006