

Variability of Soil Properties under Continuous Irrigation Farming in Nigerian Savanna

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Abstract

This study examined variability of soil properties under continuous cultivation in the Nigerian Savanna. Bulk soil samples were collected from eight irrigated farm plots and one uncultivated field during both wet season (WS) and dry season (DS) respectively. The samples were analyzed for Sand, silt, clay, bulk density, porosity, moisture content, pH, organic matter, total nitrogen, available phosphorus, exchangeable cations (Ca, Mg, K, and Na), exchangeable acidity (H+Al), exchangeable cation exchange capacity (ECEC) and base saturation which are the key soil fertility parameters. Percentage equivalence value of soil property was computed by expressing the mean value of each soil property in WS as a percentage of the mean value of the same property over the DS. From the results, the soil textural grades remained loamy in both seasons. The mean values obtained at topsoil during WS and DS are: sand (50.38 & 51.38%), silt (39.63 & 38.63%), clay (10% each), bulk density (1.38 & 1.42), porosity (47.75 & 64.04%), moisture content (0.26 & 0.19cm³), pH (5.7 & 6.03), organic matter (1.62 & 0.62%), total N (0.12 & 0.08%), available phosphorus (58.36 & 48.25mgkg⁻¹), cations [Ca (7.76 & 6.17cmol/kg⁻¹), Mg (1.48 & 1.15cmol/kg⁻¹), K (0.36 & 0.21cmol/kg⁻¹), and Na (0.61 & 0.25cmol/kg⁻¹)], H+Al (0.59 & 0.50cmol/kg⁻¹), ECEC (10.63 & 8.26cmol/kg⁻¹) and base saturation (93 & 92%). These results suggest that land use has both direct and indirect effects on the variability of soil properties.

Key words: Continuous cultivation, Soil properties, Soil variability, Zaria.

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Introduction

The most ancient and widespread farming system in the Nigerian dry region is probably the floodplain (fadama) cultivation. FAO estimated in 1986 that about 800,000ha of land were under small-scale water control project in Nigeria. Today, the figure definitely should be higher than this, as a result of the activities of the World Bank Assisted Fadama Project in the country. The practice makes dry season farming possible and thus help in making available vital farm products, as well as reducing rural unemployment problem during the long dry period. The practice relies on the traditional irrigation techniques commonly referred to as shadoof to supplement residual moisture on the hydromorphic soils of the fadama. In many areas, this shadoof is gradually being replaced by use of small diesel or petrol engine pumps to lift water, either from a nearby river, or from a shallow well or borehole sources on the fadama.

Soil infertility, the fadama soils inclusive. and land degradation has been considered as some of the major constraints facing agricultural productivity in Nigerian Savanna. To meet the food requirement of increasing human population in the area, agricultural lands have been subjected to overuse such as continuous cultivation, bush burning and other anthropogenic activities (Onwudike, 2010). In the past, agricultural system in Nigeria relied mainly on shifting cultivation to maintain the fertility of the soil through organic and plant nutrient built up during the fallow periods. But the ever-increasing population pressure on land and the rate at which prime agricultural land are lost to other non-agricultural uses with resultant decline in output per hectare of food crops due to continuous cropping, necessitated that every hectare of land should be used in accordance with its capacity and limitations. The degree of land degradation is very high and it is on the increase (Ayoub, 1994),

hence, the amount of good agricultural land is dwindling with time.

Understanding changes in soil quality due to land use practices has become very essential especially in this era where food security is a global concern (Carter *et al.*, 2004). The knowledge of the variations and changes of soil properties due to land use is vital for refining the effects of agriculture on environmental quality (Cambardella, *et al.*, 1994). The effects of cropping systems and management practices on soil properties provide essential information for assessing sustainability and environmental impact (Ishaq and Lal, 2002). In addition, many researchers reported that change of land use such as long-term cultivation, deforestation, overgrazing and mineral fertilization can cause significant variations in soil properties, terrestrial cycles and reduction of output (Tate *et al.*, 2004; Fraterrigo *et al.*, 2005; Hacısalihoglu, 2007). While some information is available for rain-fed agriculture in Nigeria, relatively little abound for irrigated land. This study was undertaken to assess the changes in soil properties under long-term continuous irrigation farming of the fadama in the Zaria region. The objectives were to determine some key soil properties under wet season and dry season irrigation farming in Zaria and to compare the same properties under wet and dry seasons.

Location of sampling sites

The study was undertaken in Dankache area of Zaria, located between latitudes 11° 04' and 11° 05'N and longitudes 7° 43' and 7° 44'E (Fig. 1). It falls within the tropical savanna climate with distinctive wet and dry seasons. It has a mean annual rainfall of 970mm. The geology of the study area is part of the Basement complex rocks, the plains attain elevation ranging from about 550m to 740m above sea level (ASL) and are underlain by pre-Cambrian rocks of variable

composition. The major soil type of the study area is tropical ferruginous, while along the wide gentle sloping valleys are vertisol and fadama soils. The area falls within the guinea savanna region and therefore most of the vegetation have been degraded due to human activities.

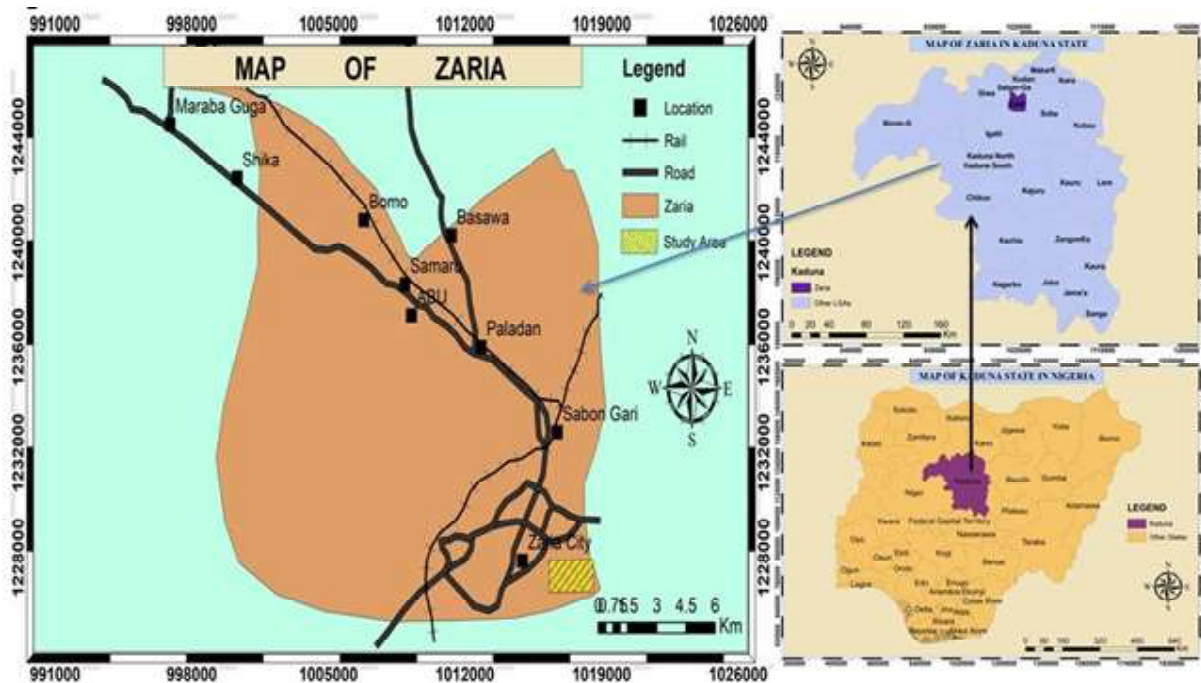


Fig 1: Location of the Study Area

Materials and Methods

Selection of soil sampling plots

Eight different irrigation farm plots together with one uncultivated plot under long standing fallow were selected for the study. The size of the farm plots ranged from 0.3 to 0.5 hectares. The selection of the plots was necessarily constrained by unavailability of reliable information on the history of use of cropping plots in the area, as narrated by owner farmers, and the need to keep, as much as possible, influencing factors other than cropping history under control. The assumption behind this is that if other major influencing factors were the same, the likelihood of error in the interpretation of results arising from heterogeneity of habitat, particularly the initial soil spatial variability, would be minimal.

The entire area is underlain by similar geology and because they are all confined within a single drainage basin, they can be assumed to experience

the same climatological condition. The vegetation cover comprises grasses which are mostly annual, dominated by species such as *Eragrostis aspera*, *Eragrostis tremula*, *Pennisetum pedcellatum*, *Rhynchelytrum repens*. The *rhizomatous perennal*, *Imperata cylindrica*, after a survivor from previous cultivation often accompany them. The plots are essentially devoid of trees.

The history of land use over the plots was also roughly similar. Across the area, the fadama is used for rice cultivation during the floods and recessions cropping after floods have receded. Most farmers construct bunds, commonly 0.4 - 0.5m high, or dykes which are higher than 1.0m, around their fields to limit the extent of damage caused by flooding. Water is let into the field by breaking the bunds or opening inlet channels, which are closed with mud or bags filled with sand. Others cultivate fields on either riverside fadamas or on extensive floodplain fadama were the construction of bunds and dykes is very difficult

because of topographical and hydrological condition.

The major irrigated crops cultivated in the dry season are pepper, okra, water melon, tomato and onion. The land is irrigated by flooding small basin, each approximately two metres square. Besides, since the mid-1980s, wet season cultivation of maize using supplementary irrigation has continued in most areas. Farmers plant maize with the first rains in May or June and irrigate three or four times or less until the rains is established. Some of the dry season crops are similarly occasionally planted with supplementary irrigation before the rains to mature under rainfed conditions. Use of manure on irrigated farmland is very rare. Use of chemical fertilizer is the principal way in which soil fertility is maintained. There are high returns to irrigation crop production as most high valued crops are involved.

The management of recession fields varies considerably depending upon the speed of flood recession, the height of the water table, and the nature of the soil. Sandy or loamy soils for example, are considered best and, where the water table is high, cropping may continue up to the start of the rains. However, this type of system is only found in limited areas around the permanent water bodies. Around the edge of flooding land, there is a zone that floods only briefly, or not at all, but which has a high-water table for much of the year. This zone is used for planting of orchards of mango and guava. Fadama land is grazed by cattle in the dry season and competition between farmers wishing to plant recession crops and pastoralists is a major cause of conflict. In some areas this competition greatly reduces the extent of recession cultivation.

Soil Sampling Procedure

Each of the eight irrigated farm plots and the one uncultivated field selected were partitioned

into twelve quadrants and numbered accordingly. All the even numbered quadrants were selected for soil sampling. Soil samples were collected at two standard depths, namely; 0-15 cm (topsoil) and 15-30 cm (sub-soil) depths. Two sets of soil samples were collected from each sampling depth. The first was the undisturbed sample with the aid of soil auger and bulk density ring used for determination of bulk density, moisture content and porosity while the second was the disturbed sample with the aid of hand trowel for determination of other soil properties. In all, 108 soil samples were collected for each season making a total of 216 for the two seasons. The undisturbed soil samples were treated immediately in the laboratory while parts of the disturbed six samples randomly collected from each of the two depths of the selected plots were bulked, thoroughly mixed and a representative sub-sample was taken, air dried, passed through 2mm sieve and stored in plastic bags for laboratory analysis.

Laboratory Analysis of Samples

The soil properties were determined by using standard laboratory procedures as indicated below. Particle sizes distribution was determined by the hydrometer method while bulk density and moisture content (MC) by oven-dried method (as expressed by the weight of the soil before and after over-dried and the volume of the soil). Porosity was calculated from bulk density and specific particle density of quartzite (2.65g/cm^3). Soil pH in CaCl_2 (0.01M) was determined using glass electrode pH meter. Walkey-Black digestion method was used for organic carbon as Kjeldahl method was used for total nitrogen. Available phosphorus was determined by Bray No. 1 method. Exchangeable K and Na were determined by flame photometer while exchangeable Mg and Ca were by atomic absorption spectrophotometer (AAS), following extraction with 1M NH_4 , OAC (pH 7.0). Exchangeable acidity (Al + H) was determined

by using 1N KCl method while base saturation was calculation from exchangeable cations and CEC.

Following the laboratory analysis of samples, descriptive statistics was used to analyze the data. The data were stratified into the different plots and the two selected soils horizons. Percentage equivalence value of soil properties was computed by expressing the mean value of each soil property in WS as a percentage of the mean value of the same property over the DS.

Results and Discussion

Table 1 shows the mean values of soil properties in WS and DS. The mean values of soil properties in WS is expressed as a percentage of the mean value of the same property over the DS.

Table 1: Mean values of Soil Properties in Wet Season (WS) and Dry Season (DS)

Property	Depth (cm)	Cropping field			Uncultivated field		
		Wet Season*	Dry Season	% Change	Wet Season*	Dry Season	% Change
Sand (%)	0-15	50.38	51.38	-2.0	44	60	-50.0
	15-30	46.75	47.75	-2.1	40	52	-30.0
Silt (%)	0-15	39.63	38.63	2.2	46	30	34.8
	15-30	42.75	38.75	9.4	46	32	30.3
Clay (%)	0-15	10	10	0.0	10	10	0.0
	15-30	13	13.5	-3.9	14	16	-14.3
Bulk Density g cm ⁻³	0-15	1.38	1.42	-2.9	1.30	1.50	-15.4
	15-30	1.47	1.52	-3.4	1.36	1.47	-8.1
Porosity (%)	0-15	47.75	46.04	3.6	51	45.27	11.2
	15-30	43.63	42.96	1.5	49	44.72	8.7
Moisture Content (cm ³)	0-15	0.26	0.19	26.9	1.17	0.23	80.3
	15-30	0.23	0.19	17.4	0.14	0.21	-50.0
Soil pH	0-15	5.7	6.03	-5.3	5.0	5.0	0.0
	15-30	5.8	5.88	-1.7	4.8	4.7	2.1
Organic Matter (%)	0-15	1.74	1.62	6.9	1.52	1.31	13.8
	15-30	1.16	0.62	46.6	1.18	0.57	51.7
Total Nitrogen (%)	0-15	0.12	0.08	33.3	0.04	0.02	50.0
	15-30	0.11	0.08	27.3	0.09	0.07	22.2
Available phosphorous (mg kg ⁻¹)	0-15	58.36	48.95	16.1	6.13	10.50	-71.3
	15-30	33.16	22.75	31.4	6.13	7.00	-14.2
Ca (cmol/kg ⁻¹)	0-15	7.67	6.17	7.5	2.29	1.42	38.0
	15-30	4.55	3.40	25.3	1.43	2.14	-49.7
Mg (cmol/kg ⁻¹)	0-15	1.48	1.15	22.3	0.81	0.69	14.8
	15-30	1.05	0.74	29.5	0.36	0.83	-130.6
K (cmol/kg ⁻¹)	0-15	0.36	0.21	43.0	0.35	0.15	57.1
	15-30	0.15	0.11	26.7	0.14	0.11	21.4
Na (cmol/kg ⁻¹)	0-15	0.61	0.25	59.0	0.37	0.15	59.5
	15-30	0.26	0.25	3.9	0.30	0.17	43.3
H+AL (cmol/kg ⁻¹)	0-15	0.59	0.5	15.3	0.20	0.40	-100.0
	15-30	0.49	0.48	2.0	0.40	0.40	0.0
ECEC (cmol/kg ⁻¹)	0-15	10.63	8.26	22.3	4.24	2.82	33.5
	15-30	6.45	4.98	22.8	2.63	3.65	-38.8
Base Saturation (%)	0-15	93	92	1.1	95	86	9.5
	15-30	90	89	1.1	85	89	-4.7

* Source: Yakubu and Mallo (2019)

The textural class of the soils remained loamy sand in both seasons, but there are percentage variations in sand, silt & clay contents between the two seasons. For instance, the mean values of the sand fraction of the cropping field during the WS decreased by 2% at the top soil and 2.1% at the sub soil respectively relative to that of DS. In the uncultivated field, the mean value decreased by 50% and 30% respectively at the top and sub soils. The dominant value of sand fraction in the soils may be attributed to the secondary product of weathering (Fitzpatrick, 1980; Yakubu, 2010). The silt particles of the cropping field on the other hand increased by 2.2% at the top and 9.4% at the sub soil in WS relative to the DS while on the uncultivated field it increased by 34.8% and 30.4% in WS relative to the DS.

Contrary to the sand and silt fraction, the clay content has the same value of 10% at top layers in both seasons on the cropping field. At the sub soil layer; it has mean value of 13% and 13.5% respectively. The comparatively lower topsoil clay content over the sub soil might be a reflection of the translocation of clay particles from the topsoil to lower horizon leading to the clay-enriched sub-soil called argellic horizon. The probable reason for the slight decrease of the clay content during the WS over the DS may be due to the impact of rainfall leaching the materials down ward before the next land preparation for cropping. Generally, the lower clay fraction of the soil in the area may be attributed to nature of the parent material (Brady and Weil, 2002).

The bulk density on the other hand is higher in DS than in WS by 2.9% (top) and 3.4% (sub) soils respectively. The improvement in bulk density could rightly be attributed to the use of simple implements and the farm management practices adopted in the irrigation farming of the selected plots have not affected the bulk density negatively. Similarly, the $1.75\text{g}/\text{cm}^3$ threshold

level of soil bulk density, suggested by Jones and Wild (1975) by which crop roots fail to penetrate the soil has not been reached.

The total porosity improved in WS relative to DS by 3.6% and 1.5% on the top and sub soils respectively of the cultivated field while at the uncultivated field, it increased by 11.2% and 8.7% at both layers respectively. Brady and Weil (2002) indicated that a high porosity value could be attributed to continuous cropping, which often results in a reduction of micro pore spaces on the agricultural plough layer or soil surface.

At the surface, the mean moisture content is 0.26cm^3 and it decreased to 0.23cm^3 at the sub surface during WS of the cropping field while in DS, the mean values remained 0.19cm^3 at both layers. The moisture content improved in WS relative to DS by 26.9% and 17.4% on the cropping field and 80.3% (top) on the uncultivated field.

Soil pH is the major driver of soil fertility (Brady and Weil, 2002). The mean soil pH reduced by 5.3% and 1.7% in WS over DS in each of the layers respectively on the cropping field. Its values for both top and sub soils were 5.7 and 5.8 in both layers in WS while the values increased to 6.0 and 5.9 in DS which is slightly acidic. At the uncultivated field, the sub soil increased by 2.1%.

Organic matter rating on individual plot ranges from low to medium. It has mean 1.74% (top) and 1.16% (sub) in WS while in DS, it has mean of 1.62% (top) and 0.62% (sub) soils in the cropping field. Soil organic matter increased in WS relative to DS by 6.9% (top) and 46.6% (sub) on the cropping field and 113.8% (top) and 51.7 (sub) on the uncultivated field. The mean organic matter content is low and it was corroborated by (Jaiyeoba, 2003; Yakubu, 2012; Mustapha *et al.*, 2011) for soils in the savanna zone of Nigeria. The low organic matter may be attributed to the prevailing dry conditions, where the biomass

production is low and the rate of mineralization is high.

Based on the ratings for soil fertility classes in the Nigerian savanna (Holland *et al.*, 1989), soil total nitrogen is rated very low with a weight of 0.12% at top soil and 0.11% sub soil layer in WS while it has the weight of 0.08% at both top and sub soil layer in DS on the cropping field. The low TN content obtained could be attributed to rapid rate of organic matter decomposition, high rate of leaching, soil erosion, volatilization and denitrification among other factors (Ekwonya and Ojanuga, 2002).

The mean values of available phosphorus significantly decreased from 58.36 (top) and 33.16 (sub) mg kg⁻¹ respectively in WS to 48.95 (top) and 22.75 mg kg⁻¹ (sub) layers in DS for the cropping field. On the cropping field, available phosphorus increased by 16.1% at the top and 31.4% at the sub soil in WS relative to DS while on the uncultivated field, it decreased by 71.3% (top soil) and 14.2% (sub soil) in WS relative to the DS. These values in comparing with Holland *et al.* (1989), ranged from high (30 – 50 mg kg⁻¹) to very high (≥50 mg kg⁻¹).

The high mean values of AP could either be attributed to phosphorous sorption or residual application of chemical fertilizer containing phosphorus from the previous farming year. According to Kparamwang *et al.*, (1998), such exceptional high value of AP could be attributed to the nature of phosphorus, which is not quite immobile and tends to remain at the surface where it is applied, unless thoroughly ploughed in the soil.

Mean values of soil exchangeable bases range from low: Ca (2-5); Mg (0.3-1.0); K (0.2-0.3) and Na (0.1-0.3) to high: Ca (10-20); Mg (3-8); K (3-8) and Na (0.7-2.0) (Holland *et al.*, 1989). A general increase of soil exchangeable bases was

observed in WS over the DS. For instance, there is an increase of 7.5% and 25.3% (Ca), 22.3% and 29.5% (Mg), 43.0% and 26.7% (K) and 59% and 3.9% (Na) at both top and sub soils of WS over DS on the cropping field. The uncultivated field showed different trend. For instance, with the exception of K and Na that showed increase at the sub soils, both Ca and Mg indicated decrease at the sub soils.

The values of exchangeable acidity on the cropping field in WS at the top and sub soils are 0.59 and 0.49cmol/kg⁻¹ while the values obtained in DS are 0.50 and 0.48cmol/kg⁻¹ respectively. Generally, the exchangeable acidity is very low and suggesting that the soils have no acidity problem. While the percentage change was on the increase at the cropping field 15.3% (top) and 2.0% (sub), it decreases on the uncultivated field 100% (top) and 0 (sub) on the uncultivated field respectively.

The exchangeable cation exchange capacity (ECEC) mean value in WS top and sub soils are 10.63cmol/kg⁻¹ and 6.45cmol/kg⁻¹ while in DS, they are respectively 8.26cmol/kg⁻¹ and 4.98cmol/kg⁻¹ on the cropping field. These showed an increase of 22.3% and 22.8% respectively in WS relative over DS. On the uncultivated field, it indicated an increase of 33.5% (top soil) and a decrease of 38.8% (sub soil) respectively. Although these values are higher than the value of 7.9 to 10.7cmol/kg⁻¹ obtained by Yakubu (2012), the mean values are rated low. The low fraction of clay and organic matter of the soils are responsible for the low cations retaining ability and hence it's low capacity to hold nutrients against leaching.

The soils have very high base saturation at both layers. The means values in WS are 93% and 90% (top and sub soils) respectively while in DS, the mean values are 92% and 89% on the cropping field. This shows an increase of 1.1% at both soil

layers in WS over the DS. The uncultivated field on the other hand showed an increase of 9.5% (top) and a decrease of 4.7% (sub) soils respectively.

These results presented in this study are in concord with the results of Chen and Xu (2010) and Onwudike *et al*, (2015) who indicated that land use, farming management practices, micro and macro climate in land use types significantly affect the content of soil properties.

Conclusion and Recommendation

Soil as a natural resource must be utilized efficiently in both short and long terms to make agriculture more sustainable. The main aim of the study was to assess seasonal variation of soil properties under continuous irrigation farming in Nigerian savanna. From the results obtained, with the exception of sand, clay (at the sub soil), bulk density and pH where the percentage equivalent values were lower in wet season relative to dry season, the percentage equivalent values of all other soil properties examined were higher in wet season relative to dry season. There were variations in soil properties among the eight cultivated lands and the uncultivated field. Variations existed among soil properties in both dry and wet seasons and between the cultivated and uncultivated fields. These variations could be due to management practices, constant anthropogenic activities and differences in the level of organic activities which ranges from the use of fertilizers of organic origin such as compost manure, green manure, bone meal and emphasis on techniques such as crop rotation to enhance the fertility status of the soil. Generally, the studied soils can be regarded as fertile soil for agricultural production if well managed. Although the use of external input such as organic and inorganic fertilizers is common in the area, sustainable agricultural production in the area can only be possible through the use of appropriate

measures of these inputs in addition to appropriate management techniques to augment the natural endowment.

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Conflict of Interest

The authors declare no conflict of interest.

References

- Ayoub, A.T. (1994). Human induced soil degradation in Africa: In Bhushan, L.S.; Abrol, I.P.; Rama, M.S. and Rao, M (eds). Proc. 8th International Soil Conservation Conference. 34-42.
- Brady, N.C. and Weil, R.R. (2002). The Nature and Properties of Soils. 13th edition Prentice - Hall, Ina, New Jersey.
- Cambardella, C. A., Moorman, T. B., and Novak, J. M., 1994. "Field-scale variability of soil properties in central Iowa soils." Soil Science Society of America Journal, vol. 58, pp. 1501 - 1511.
- Carter, M. R., Andrews, S. S., and Drinkwater, L. E., 2004. "Systems approaches for improving soil quality." In: Managing Soil Quality: Challenges in Modern Agriculture (Schjonning P, Elmholt S, Christensen BT, eds). 261 -281, CABI International, Wallingford, UK.
- Chen, C. and Xu, Z., 2010. "Forest ecosystem responses to environmental changes: The key regulatory role of biogeochemical cycling." J. of Soils Sediments, vol. 10, pp. 210 – 214.

- Ekwonya, M.A. and Ojanuga, A.G. (2002). Productivity assessment of upland and floodplain soils at Makurdi, Nigeria. *Geoderma*, 108: 19-29.
- Fitzpatrick, E.A. (1980). *Soils - their formation, Classification and Distribution*. Longman, London. Pp 335.
- Fraterrigo, J.M., Turner, M.G. Pearson, S.M. and Dixon, P. (2005). Effects of past land use on spatial heterogeneity of soil nutrients in southern Appalachian forests ecological monographs. *The Ecol. Soc. Am.*, 75, 215-230.
- Hacisalihoglu, S. (2007). Determination of soil erosion in a steep hill slope with different land-use types: A case study in Mertesdorf (Ruwertal/Germany). *J. Environ. Biol.*, 28, 433-438.
- Holland, M.D., Allen, R.K.G., Berton D. and Murphy S.T. 1989: *Land Evaluation and Agricultural Recommendations*. Cross River National Park, Urban Division. Prepared by ODNRI in collaboration with WWF.
- Ishaq, M.I. and Lal, R. (2002). Tillage effects on soil properties at different levels of fertilizer application in Punjab, Pakistan. *Soil Tillage Research*. 68, 93-99 (2002).
- Jaiyeoba IA (2003) 'Changes in soil properties due to continuous cultivation in Nigerian semiarid Savannah' *Soil & Tillage Research* 70, 91-98.
- Jones, M.J and Wild, A. (1975). *Soils of the West African savanna*. Technical Communication No. 55 of the common wealth Bureau of soils, Harpenden.
- Landon, J.R. 1991: *Booker Tropical Soil manual: A handbook for soil survey of agricultural land evolution in the tropics and subtropics*. John Wiley & sons Inc. 605, third Avenue, N.Y. USA. Pp 450.
- Mustapha, S.; Voncir, N.; Umar, S. and Abdulhamid, N.A. (2011). Status and Distribution of some available micro-nutrient in the Haplic Usterts of Akko Local Government Area, of Gombe State, Nigeria. *International Journal of Soil Science*, 10: 1-8.
- Onwudike, S.U. (2010). "Effectiveness of Cow Dung and Mineral Fertilizer on Soil Properties, Nutrient Uptake and Yield of Sweet Potato (*Ipomoea batatas*) in Southeastern Nigeria." *Asian Journal of Agricultural Research*, vol. 4, pp. 148-154.
- Onwudike, S.U., Ihem, E.E., Irokwe, I.F. and Onwuso, G. (2015). Variability in the Physico-chemical Properties of Soils of Similar Lithology in Three Land Use Types in Ahiazu Mbaise, Imo State Nigeria *Journal of Agriculture and Crops*. Vol. 1(3), 38-43, ISSN: 2412-6381
URL: <http://arpgweb.com/?ic=journal&journal=14&info=aims>
- Kparmwang, T., Abubakar, A.S, Chude, V.O., Raji, B.A. and Malgwi, W.B. (1998). The Inherent Fertility and Management of the Micro-topographical land features of River Galma at Zaria. *Proceedings of Soil Sciences Society of Nigeria*, held at Bauchi. Pp 124-130.
- Tate, K., Wilde, R. H., David, J., Giltrap, W. T., and Saggat, S. B., (2004). "Soil carbon changes and uncertainties with New Zealand land-use change, Super Soil." 3rd Australian New Zealand Soils Conference, 5-9 December 2004, University of Sydney, Australia.
- Yakubu, S. (2012). Changes in Soil Chemical Properties due to Different Land Uses in Part of Nigerian Northern Guinea Savanna. *The Nigerian Geographical Journal*, Volume 8(2), 142-155.
- Yakubu, S. (2010). Changes in Soil Physical Properties due to Different Land Uses in Part of Nigerian Guinea Savanna. *Zaria Geographers*. Published by the department of Geography, Ahmadu Bello University Zaria. 18(1), 47-56.
- Yakubu, S. and Mallo, I.I.Y. (2019). Assessment of Soil Fertility Status under Continuous Irrigation Farming in Nigerian Savanna. *Ghana Journal of Geography* Vol. 11(2), 2019 pages 227-242.