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ASSESSMENT OF SOIL VARIABILITY UNDER DIFFERENT LAND USE IN NORTHERN GUINEA SAVANNAH ZONE OF KADUNA STATE, NIGERIA

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ABSTRACT

The relative influence of land use on soil variability was examined for an extensive group of soils in Kaduna to provide an understanding of soil variability on dynamic properties of soil for suitable land use and avoidance of environmental degradation. The study examined the impact and variability in soil chemical properties in the three land use systems. Soil samples were randomly collected and replicated three times in a pasture, irrigated and arable land uses located within Zaria and its environs, Kaduna state. Result on impact of the land use systems on soil properties revealed that while soil pH, organic carbon, exchangeable acidity, exchangeable calcium and magnesium were statistically similar in pasture and irrigated land uses, they were significantly ($P < 0.001$) higher in arable land uses. Similarly soils under pasture was significantly ($P < 0.001$) higher in total nitrogen, available phosphorus, and soil cation exchange capacity than those under irrigation and arable land. The result on soil variability between the three land use types showed that Organic carbon, Total nitrogen, Available phosphorus, Exchangeable magnesium, exchangeable potassium, exchangeable sodium, total exchangeable bases, exchangeable acidity and cation exchange capacity showed coefficient of variations (CV) >35% in pasture and irrigated land uses while exchangeable acidity, total nitrogen and organic carbon were highly variable (CV>35) in arable land use. In conclusion, variability analysis of the sites indicated that the soil properties examined showed a dynamic relationship between land use types.

Keys words: Soil management, variability,

INTRODUCTION

Due to heterogeneous nature of Soils; they exhibit significant variability in their physical, chemical, and biological properties. These Variations have been found to influence crop production as well as soil management practices significantly (Fasina, 2003). In addition to intrinsic soil variations, other elements contribute to soil variability, such as variations in weathering rates and other soil-forming variables like climate, parent materials, organisms, relief, and time (Udoh *et al.*, 2006). Through a variety of land use practices, fertilizer application, soil management techniques, and land use changes, man has also contributed to soil variability (Maniyunda *et al.*, 2013, Sufiyanu et al., 2022). By transforming the processes of nutrient transport and its redistribution, land-use systems and soil management practices affect soil nutrients and associated processes such as erosion, oxidation, mineralization, leaching, and so forth (Celik, 2005; Liu et al., 2010). These lead to variability in the properties of the soil. Uniform field management generally leads to over application of inputs in low-yielding areas and under application of inputs in high-yielding areas because of spatial variation within the field. (Davis et al., 1996, Ferguson et al., 2002, Sani *et al.;* 2023, and Amin *et al.;* 2019).

Great variability of soil resources had been reported in dryland areas mainly as a result of plant species distribution patterns (Wezel *et al*., 2000; CongJuan *et al*., 2010). According to Wezel et al. (2000), different plant species contribute to the diversity of soil properties as a result of their varied minerals uptake and formation of distinct soil horizons. In a similar vein, Romney et al. (1980) and CongJuan et al. (2010) linked variations in the content and mineralization of nutrients found in leaf litter to soil variability.

Spatial variability of soil resources is a common feature of natural ecosystems and has been recognized as a key driver of biological processes (Zhou et al., 2008; Li et al., 2010) as well as an essential element of competitive or cooperative plant-plant interactions. Thus, influences the biogeochemical cycles in many ecosystems and can also generate landscape patterns (Liu et al., 2010, Abdulkadir et al., 2020). The variation of soil properties should be closely monitored and quantified in order to understand the impacts of land use and management systems on such soils.

MATERIALS AND METHODS

Land Use Selection

The pasture field consisted of a mixture of *Brachiaria decumbens*, *Digitaria smutsii* and a mixture of both grasses is located on the research fields of the National Animal Production Research Institute (NAPRI), Shika, Zaria, Kaduna State, Nigeria. Grazing is restricted to the dry season on the pasture lands, and baling takes place immediately after November's rains. Available records indicated that the fields have been consistently covered by the same planted pasture and have not experienced a fire since 1963. The irrigated field is situated near Dakace along the Galma floodplain in Zaria area of Kaduna state. Agriculture is booming in this floodplain. This floodplain is used for year-round cropping and cultivation. The Gabari village field was chosen for arable (rain-fed only) farming.

The geology of all sites is basement complex composed chiefly of coarse-grained granite, fine grained gneisses and migmatite. The gneisses are weakly floated, primarily made of quartz and oligoclase (Ugumanin *et al*., 2015). All the study sites lie within the Northern Guinea Savanna ecological zone with monomodal annual rainfall of about 1011±161 mm concentrated almost entirely in the five months (May/June to September/October), and mean daily temperatures (minimum and maximum) range between 15°C and 38°C. Unfortunately, the characteristic of this vegetation is drastically changed due to urbanization, anthropogenic activities and poor agricultural management practices such as cultivation, grazing and associated trampling by animals, fuel wood harvesting and bush burning by farmers as usually practiced in the study area. (Ugumanin *et al*., 2015).

Soil sampling and Analysis

Soil samples were randomly collected from each land use types and replicated three times. The collected soil samples were air-dried, gently crushed and sieved to remove materials greater than 2mm.

Soil properties	**Methods used**
Particle size analysis	Bouyoucos hydrometer method (Gee and Bauder, 1986).
Soil Ph	1:1.5 soil/water ratio and the saturation extract was also used to obtain electrical conductivity
Soil EC	Saturated paste extract
Bulk density	Tube core method (Blake and Hartge1986)
Exchangeable bases (Ca, Mg, K, and Na)	Ammonium (NH_4OAc) saturation method at pH 7
Cation Exchange capacity (CEC)	Ammonium (NH_4OAc) saturation method at pH 7
Exchangeable acidity	Thomas (1982).
Percentage Base saturation percentage (PBS)	calculation, using proportion of exchangeable bases and CEC
Soil Organic carbon	Walkley-Black dichromate wet oxidation method (Nelson and Sommers, 1982)
Total nitrogen (TN)	micro-Kjeldahl Bremner and Mulvaney (1982)
Available phosphorus (AvP)	Bray I method as described in Estephan *et al.; 2013* and IITA (1979) laboratory manual.

Statistical analysis

To determine the Variation in soil properties within and between the different land use types was measured by estimating the mean (x), Standard deviation (SD), variance and the coefficient of variation (CV). Properties with larger CV values are more variable than those with smaller CV values. Wilding (1985) and Ogunkunle (1993) described a classification scheme for identifying the extent of variability for soil properties based on their CV values, in which CV values of 0-15, 16-35 and > 36% indicate low (least), moderate and high variability, respectively. The extent of soil heterogeneity was analysed using the general linear model procedure of the statistical analysis system (SAS, 1999). Analysis of variance was used to determine the impact of different land use on soil chemical properties and least significance difference (LSD) test was used to separate significantly differences after main effects were found.

RESULT AND DISCUSSION

Table 1. Shows the results of the impact on different land-uses on soil chemical properties in the study area. Soil pH was rated neutral under arable land use and was found to be significantly ($P < 0.001$) higher than soils under irrigation and pasture land use which were both rated moderately acidic (Table 1). Soil Organic carbon was all rated low under all the land-uses. Soil Organic carbon (SOC) under irrigation and pasture land-uses were significantly ($P < 0.01$) higher than soils under arable land. Lower amount of organic carbon under arable land-use may be as a result of crop residues removal (Awasthi *et al*., 2005, Noma and Sani, 2008) and intensive tillage operation due to continuous farming which lower nutrient concentration thereby declining fertility which is in agreement with the findings of Pandey et al., 2018 and Abdulkadir et al., 2022).

Table 1. Impact of land-use on soil chemical properties

Land use	pH	OC	TN	AvP	Ca	Mg	K	Na	TEB	EA	CEC	BS
		g/kg	g/kg	mg/kg	--------------------------cmol/kg--------------------------							%
Pasture	5.69b	6.37a	1.34a	12.83a	7.91a	2.61a	0.48a	0.61a	11.60a	0.87a	17.30a	72.00a
Irrigated	5.85b	9.62a	0.52b	8.49b	7.52a	1.92a	0.15a	0.48a	10.10a	0.91a	10.90b	65.00a
Arable	6.68a	0.48b	0.02c	3.07c	4.27b	0.45b	0.14a	0.38a	5.30b	0.33b	8.50b	62.00a
P-value	0.0002	0.006	<.0001	0.001	0.003	0.001	0.17	0.67	0.002	0.05	0.009	0.45
LOS SE+	***	**	***	**	**	**	NS	NS	***	*	**	NS

OC=organic carbon, TN=Total nitrogen, AvP=Available phosphorus, Ca=exchangeable calcium, Mg=exchangeable magnesium, K=exchangeable potassium, Na=exchangeable sodium, TEB=Total exchangeable bases, CEC=cation exchange capacity, BS=Base saturation

Total nitrogen was rated low under all the land uses, but soils under pasture was found to be significantly ($P < 0.001$) higher total nitrogen than those under irrigation, and irrigation was also significantly ($P < 0.001$) higher than arable land.

The result supports the findings of Dunguma *et al.* (2010) who reported higher total nitrogen in pasture land compared to agricultural lands. In addition, Yimer et al. (2006) also reported that soil organic carbon (SOC) and total nitrogen content were significantly lower in arable land use compared to grazing and forest land. Land use significantly ($P < 0.01$) influence the soil available phosphorus. Available phosphorus was significantly ($P < 0.01$) higher and rated medium under pasture, those under irrigation was also significantly ($P < 0.01$) higher than arable land was both rated low. Higher available phosphorus values under pasture could be due to litter accumulation as reported by Sani *et al.;* 2024a, Gong *et al.; (*2022) and DeBano (1991) and the increased availability of plant materials such as lignin (Zhang *et al*., 2017).

The application of manure and fertilizer, among other things, and various soil management techniques can both affect the variation in soil nutrients within agricultural land (Sherchan and Gurung, 1995). Furthermore, tillage, crop residue collection, and reduced carbon inputs can all result in a decrease in soil nutrients in agricultural soils (Wang et al., 2001). Exchangeable calcium and magnesium levels in pasture and irrigation areas were considerably ($P < 0.01$) higher and classified high compared to arable lands, which were rated medium and low, respectively. Arable and irrigated soils received poor ratings for exchangeable potassium, but grazing land received a high rating. The salt concentration of every land use was rated high. The exchangeable acidity and cation exchange capacity of soils under pasture and irrigation were substantially ($P < 0.05$) greater than those under arable land. Base saturation was rated high under all the land uses and were statistically similar. Low concentration of exchangeable cations in the arable and irrigation land could be as a result of nutrient mining through continuous cultivation and crop residue removal to feed farm animals.

Higher exchangeable cations in pasture could be due to low disturbance and higher organic matter under the land use as compare to arable land. Additional organic carbon stocks in the soil increases the soil cation exchange capacity (CEC), which in turn reduces the leaching rate of exchangeable bases (Mbah, 2008).

Similarly, the leaching of soil nutrients as a result of rainfall or irrigation water, limited or no recycling of crop residue, continuous cropping, and soil erosion have contributed to the depletion of these essential basic cations on agricultural lands compared to agroforestry (Akbas *et al.,* 2017, Dawaki et al., 2019).

The measures of central tendency used were mean and median, standard deviation and CV were used as estimates of variability (Table 2). The mean and median values were similar, with median either greater than or less than the mean for most soil properties (Table 2).

This showed that the outliers did not dominate the measures of central tendency. Shukla *et al.* (2004) also reported a similarity of means and median for several soil physical, chemical, and biological properties. Large proportion of the soil properties were highly variable under the land uses (Table 2). High variability was observed for organic carbon, total nitrogen and exchangeable acidity across all the land use (CV >35 %) as shown in Table 3. Exchangeable potassium, sodium and cation exchange capacity were highly variable (CV >35 %) in pasture and irrigated field (Table 3). These high spatial variabilities in these soil properties may be as a result of decomposition and mineralization of leaf letters and management practices such as application of manure or fertilizers in irrigation and arable farming. Maniyunda et al. (2014) reported that large proportion of soil properties under Nigeria savanna to be highly variable. They also attributed the extent of these variabilities may be due to variation in land-use types, management and cultural practices applied.

Table 2: Soil Variability in chemical properties under the land uses

Land use		pH	OC	TN	AvP	Ca	Mg	K	Na	TEA	EA	CEC	BS
Pasture	Median	5.79	3.26	1.40	12.25	7.74	3.14	0.28	0.36	12.04	0.70	16.20	73.40
	Mean	5.69	6.37	1.34	12.83	7.91	2.61	0.48	0.61	11.60	0.87	17.30	72.00
	SD	0.58	4.98	0.77	5.44	1.91	1.78	0.41	0.55	3.47	0.55	6.50	14.40
	CV	9.54	169.6	105.80	69.11	31.27	113.20	178.60	149.50	40.03	96.77	48.20	21.60
Irrigated	Median	6.07	7.60	0.40	5.95	5.66	1.53	0.07	0.47	7.98	0.60	8.40	61.90
	Mean	5.85	9.62	0.52	8.49	7.52	1.92	0.15	0.48	10.10	0.91	10.90	65.00
	SD	0.44	3.06	0.34	4.00	2.79	0.56	0.13	0.20	3.22	0.35	3.50	16.80
	CV	7.42	37.11	79.10	54.12	43.37	33.11	91.92	43.79	37.01	46.19	37.30	29.40
Rain fed	Median	6.70	0.38	0.01	2.98	3.97	0.46	0.18	0.38	5.08	0.40	8.40	59.80
	Mean	6.68	0.48	0.02	3.07	4.27	0.45	0.14	0.38	5.30	0.33	8.50	62.0
	SD	0.26	0.22	0.01	0.73	0.60	0.03	0.05	0.09	0.69	0.18	1.60	7.80
	CV	3.87	48.19	41.61	24.58	14.12	5.66	29.43	22.13	13.20	48.45	19.10	12.50

SD = standard deviation CV = Coefficient of variability

Soil properties with moderately and highly variable includes: Organic Carbon (OC), TN, Ap, Mg, Ca, K, Na, TEB, EA, CEC and BS (Table 3) and are also attributed to land use types, cultural and management practices as cropping systems, weeding, fertilizer applications, fallowing and bush burning (Maniyunda *et al*., 2014). Soil pH was least variable with Coefficient of variability (< 15 %) across all the land uses (Table 3) and the findings corroborates reports by (Sani *et al.;* 2024b, Ogunkunle, 1993; Mulla and McBratney, 2001, Oku *et al*., 2010). The Low CV for pH was attributable to the measurement unit, which was the log of the proton (H) concentration but not the concentration of H. The lower CV for pH has been reported in several other studies (Tsegaye and Hill, 1998; Shukla *et al*., 2004; Maniyunda *et al*., 2014). Base saturation which was moderately variable under pasture and irrigation land use types. This findings was in agreement with the report of Oku et al. (2010) who reported base saturation was moderately variable under Udalf toposequnce in southern Nigeria.

Table 3: Variability grouping of soil chemical properties under the land uses

Land use	Variability	C V (%)	soil chemical properties
Pasture	Least	< 15	pH
	Moderately	15-35	Ca, BS
	Highly	> 35	OC, TN, AvP, Mg, K, Na, TEB, EA, CEC
Irrigated	Least	< 15	pH
	Moderately	15-35	Mg, BS
	Highly	> 35	OC, TN, AvP, Ca, K, Na, TEB, EA, CEC
Arable	Least	< 15	pH, Mg, TEB, BS, Ca
	Moderately	15-35	AvP, K, Na, CEC
	Highly	> 35	EA, TN, OC

CONCLUSION

Results from the present study demonstrate that different land-use systems have a profound influence on the variability of chemical properties in soils. Pasture field contributes more Soil organic carbon, total nitrogen, available phosphorus, exchangeable calcium, exchangeable magnesium, exchangeable potassium and exchangeable acidity to the soil than other land use types. The comparison between soil properties in the different land use systems shows that arable land use type contributes to the decline in soil chemical properties and this decline may be interpreted in view of the degradation of the soil. Soil pH is the least variable soil parameter and organic carbon, Total nitrogen and exchangeable acidity are the most highly variable soil properties. Similarly, pasture and irrigation land use types contributed more to the variability of soil properties than arable land use types. Therefore, from these study, it can be confirm that different land use types had a significant influence on the distribution of soil chemical properties. It also acknowledges that knowledge of the factors and extent of variability of soil properties within any land uses helps to assess and monitor soil degradation so as to achieve a sustainable management of soil resource in the future.

REFERENCES

Abdulkadir, A, Halilu, Y., and Sani, S. (2022). Evaluation of Physical and Chemical Properties of Soils at Bichi Local Government Area, Kano State, Nigeria. IRE Journal, 5(9), 556–562.

Abdulkadir, A., Dawaki, M. U., and Sani, M. (2019). Effect of Organic Soil Amendments on Soil Chemical Properties in Sudan Savannah of Nigeria Effect of Organic Soil Amendments on Soil Chemical Properties in Sudan Savannah of Nigeria. NJSS, 30(2), 122–132. https://doi.org/https://doi.org/10.36265/njss.2020.300215

Akbas, F., Gunal, H., and Acir, N. (2017). Spatial variability of soil potassium and its relationship to land use and parent material. Soil & Water Research, 12, 4. doi:10.17221/32/2016-SWR.

Ali Muhammad Amin, Mahmud Sani, Umar Bello Ahmad, Sani Sufiyanu, Hayatu Bashir Shehu, Aliyu Wada Rabiu and Lamido Afiya Kabir (2019). Geo-statistical Mapping of some soil fertility constraints in Sorghum based Cropping System of Sudano-Sahelian Zone of Nigeria. Azarian J. Agric 6(6): 146-152 http://dx.doi.org/10.29252/azarinj.019

Awasthi, K.D., Singh, B.R. and Sitaula, B.K. (2005). Profile carbon and nutrient levels and management effect on soil quality indicators in the Mardi watershed of Nepal. Acta Agriculturae Scandinavica Section B-Soil and Plant, 55(3), 192–204. doi:10.1080/09064710510029079

Blake, G.R. and Hartge K.H. (1986) Soil bulk density and particle density determination. In: Klute, A.

(ed.). Methods of Soil Analysis, American Society of Agronomy, Madison, Wisconsin USA.

Bremner, J.M. and C.S. Mulvaney. 1982. Nitrogen – Total, pp. 595-624. In R. Page, A. Miller and D.R. Keeney (eds.). Methods of Soil Analysis. Part 2. (2nd ed). American Society of Agronomy and Soil Science Society of America. Madison. Wisconsin.

Cambardella, C.A. and Karlen D.L. (1999) Spatial analysis of soil fertility parameters *Precision Agriculture* volume 1 pp. 5-14

Celik, I. (2005) Land-use effects on organic matter and physical properties of soil in a Southern Mediterranean highland of Turkey. *Soil Tillage Research.* 83: 270-277.

Cong Juan LI, Yan LI, Jian MA, LianLian FAN, QinXue WANG (2010), Spatial heterogeneity of soil chemical properties between *Haloxylon persicum* and *Haloxylon ammodendron* populations. Journal of Arid Land, Vol. 2, No. 4, 257−265

Davis, J.G., G.L. Malzer, P.J. Copeland, J.A. Lamb, P.C. Robert, and T.W. Bruulsema. 1996. Using yield variability to characterize spatial crop response to applied N. p. 513–519. In P.C. Robert et al(ed.) Precision Agriculture–Proc. Int. Conf., 3rd, Minneapolis. 23–26 June 1996. ASA, CSSA, and SSSA, Madison, WI

Dawaki, M. U., Abdulkadir, A., and Abdulrahman, B. L. (2020). Comparative Potential Effects of Biochar , Compost and Inorganic Fertilizer on Major Nutrient Ions Mobility and Stability in Screen - House Irrigated Maize in the Drier Savannas of Nigeria. NJSS, 29(2), 122–132. https://doi.org/https://doi.org/10.36265/njss.2020.290215

DeBano, L.F. (1991). The effect of fire on soil properties. In A. E. Harvey & L. F. Neuenschwander (Eds.) compilers, Proceedings-management and productivity of western-montane forest soils (Vol. 280, pp. 151-156). 1990 April 10-12Boise, ID. Gen. Tech. Rep. INT-280. Ogden, UT: US Department of Agriculture, Forest Service, Intermountain Research Station.

Duguma, L.A., Hager, H. and Sieghardt, M. (2010). Effects of land use types on soil chemical properties in smallholder farmers of central highland Ethiopia. Ekológia (Bratislava), 29(1), 1-14.

Estefan, G., Sommer, R., and Ryan, J. (2013)Methods of Soil, Plant, and Water Analysis: A manual for the West Asia and North, ICARDA: Bierut, Lebanon, pp65 - 67.

Fasina, S. (2003) Top soil variation of soil properties in some mapping units in a Farm in Southern Nigeria, *Journal of Sustainable Agricultural Environment*, 5(1):137-146.

Ferguson, R.B., G.W. Hergert, J.S. Schepers, C.A. Gotway, J.E. Cahoon, and T.A. Peterson. 2002. Site-specific nitrogen management of irrigated maize: Yield and soil residual nitrate effects. Soil Sci. Soc. Am. J. 66:544–553

Gee, G.W. and Or, D. (2002) Particle size analysis. In: J.H. Dane and G.C. Topp (eds). Methods of soil analysis, part 4. physical methods. Soil Science Society of America. Book series. No. 5 America Society Agronomy and Soil Science Society of America Madison, W1. Page 255-293.

Gong, J., Zhang, Z., Zhu, C., Shi, J., Zhang, W., Song, L., Li, Y., Zhang, S., Dong, J., & Li, X. (2022). The response of litter decomposition to phosphorus addition in typical temperate grassland in Inner Mongolia. Journal of Arid Environments, 197, 104677. https://doi.org/10.1016/j.jaridenv.2021.104677

IITA (International Institute of Tropical Agriculture) 1979. Selected Methods for Soil and Plant Analysis. IITA Manual Series 1, IITA, Ibadan, Nigeria. 60p

Jagruti P. Shah and Gobi A. Thivakaran 2014 GIS study on Chemical Properties of Salt Affected Soils of Coastal Kachchh, Gujarat, India Annual Research & Review in Biology 4(23): 3492-3503,

Kilic, K. Kilic, S. and Kocyigit, R. (2012) Assessment of Spatial Variability of Soil Properties in Areas Under Different Land Use. *Bulgarian Journal of Agricultural Science* Vol 18 (5): 722-732.

Li, W, Xiao-Jing, L, Khan, M. A. and Gul,B. (2008). Relationship between Soil Characteristics and Halophytic Vegetation in Coastal Region of North China. Pak. J. Bot., 40(3): 1081-1090

Liu E., Yan C., Mei X., He W., Bing S.H., Ding L., Liu Q. and Fan T. (2010). Long term effect of chemical fertilizer, straw and manure on soil chemical and biological properties in northwest China. *Geoderma* 158(3-4):173-180

Maniyunda, L.M., B.A. Raji, A.C. Odunze and W.B. Malgwi, 2014. Geochemistry of major elemental oxides on a Lithosequence in Kaduna State, Nigeria. Niger. J. Soil Sci., 24: 24-35.

Maniyunda1 L.M., Raji B.A. and Gwari M.G. (2013) Variability of Some Soil Physicochemical Properties on Lithosequence in Funtua, North -Western Nigeria. *International Journal of Science and Research* (IJSR), India Online ISSN: 2319-7064 Vol. 2(9)

Mbah, C.N. (2008). Contributions of organic amendments to exchangeable potassium percent and soil nitrate concentration in an Ultisol and their effect on maize (Zea mays L) grain yield. *Agro-Science Journal of Tropical Agriculture, Food, Environment and Extension*. Vol.7(3), 206-210.

Mulla, D.J. and A.B. McBratney. (2001). Soil spatial variability, pp. 343-374. *In* A.W. Warrick (ed.). Soil Physics Companion. CRC Press. USA.

Nelson, D.W. and Sommers, L.E. (1982) Total carbon, organic carbon, and organic matter. In A.L. Page, R.H. Miller, and D.R. Keeney (eds.) *Methods of soil analysis*. Part 2. Chemical and microbiological properties. 2nded. Agronomy. 9:539-579.

Noma, S. S; and S. Sani. (2008) Estimation of Soil organic matter Content in soils of Sokoto Area: Comparing Walkley- Black and a proposed unconventional method. *Techno Science Africana Journal 2(1) 71-76*

Ogunkunle, A.O. (1993). Variation of some soil properties along two top sequences on Quartile schist and banded gneiss in southern Nigeria. *Geoderma* 30(4): 397-402.

Ogunkunle, A.O. and Erinle, W.O. (1994) Influence of tillage on the variability of some properties of an Alfisol in Southern. *Nigeria, Journal of Science Research*. 1(1):52-57.

Oku, E., Essoka, A. and Thomas E. (2010) Variability in Soil Properties Along an Udalf Toposequence in the Humid Forest Zone of Nigeria. *Kasetsart Journal*. 44: 564-573.

Palmer, M.W. Putting things in even better order: The advantages of canonical correspondence analysis. Ecology 1993, 74, 2215–2230

Priyabrata S., Chopra, U. K. and Debashis Chakraborty (2008). Spatial variability of soil properties and its application in predicting surface map of hydraulic parameters in an agricultural farm. *Current Science*, Vol. 95(7): 937-954

Rhoades, J.D. (1982). Cation exchange capacity. In Page, A.L., Miller, R.H. and Keeney, D.R. (eds). *Methods of Soil Analysis.* Part 2 Agronomy Volume 9. Madison WI. Page 149-157.

Romney, E.M., Wallace, A., Kaaz, H. & Hale, V.Q. (1980). The role of shrubs on redistribution of mineral nutrients in soil in the Mojave Desert. Great Basin Naturalist Memoirs, 4: 122–131

Sani, S., Abdulkadir, A., Hmad Pantami, S. A., Sani, M., Amin, A. M., & Abdullahi, M. Y. (2023). Spatial Variability and Mapping of Selected Soil Physical Properties under Continuous Cultivation. Turkish Journal of Agriculture - Food Science and Technology, 11(4), 719–729. https://doi.org/10.24925/turjaf.v11i4.719-729.5733

Sani, S., Sani, M., Salihu, A. P., Aliyu, A., Yakubu, M., Garba, N. H., & Basiru, L. J. (2022). Spatial Variability of Soil Hydraulic Properties in Jibia Irrigation Project, Katsina State, Nigeria. Natural Resources and Sustainable Development, 12(2), 245–254. https://doi.org/10.31924/nrsd.v12i2.103

SAS (199). SAS/Procedure guide, Release SAS 9.1.3, Service pack 1. Cary, NC: SAS Institute.

Schlesinger, W. H., Raikes, J. A., Hartley, A. E., and Cross, A. F. (1996). On the spatial pattern of soil nutrients in desert ecosystems. Ecology 77, 364-374.

Seibert, J., J. Stendahl and R. Sorensen. (2007). Topographic influence on soil properties in boreal forests. Geoderma, 141: 139-148.

Shah, P.B., and Schreier, H. (1995). Maintaining soil fertility in agriculture and forestry. In H. Schreier, P. B. Shah, & S. Brown (Eds.), challenges in mountain resource management in Nepal: Processes, trends and dynamics in middle mountain watersheds. Workshop proceedings. Kathmandu, Nepal (pp. 171–182). Ottawa, ON: International Development Research Centre.

Sherchan D.B. and Gurung B.P. 1995. An integrated nutrient management system for sustaining soil fertility: opportunities and strategy for soil fertility research in the hills. In: Schreier H., Shah P.B. and Brown S. (eds), Challenges in Mountain Resource Management in Nepal. Processes, Trends and Dynamics in Middle Mountain Watersheds. ICIMOD, Kathmandu, Nepal, pp. 63–80.

Shukla, M. K., Lal, R., and Ebinger, M. (2004). Principal component analysis for predicting corn biomass and grain yields. Soil Science, 169, 215.

Sufiyanu Sani, Abdulkadir Aliyu, Maryam Adamu Umar, Mahmud Sani, Hamza Yahaya, Musa Muhammad, Muhammad Nasir, Zara Musa, Imrana Salisu Haruna and Kabir Muhammad Ladan (2024b). Influence of Different Nitrogen Sources on Growth and Yield Of Amaranths (Amaranthus cruentus L) in Dutsin-Ma, Katsina State, Nigeria. Agricultural Science: An International Journal (AGRIJ), Vol.1, No.2

Sufiyanu Sani, Aliyu Abdulkadir, Musa Muhammad, Musab Ibrahim, Abdulsalam Sani Nababa, Ahmad Ubaidullah and Aliyu Suleiman (2024a). Assessment of Soil Salinity and Sodicity Status at Jibia Irrigation Project, Katsina State, Nigeria. Life Sciences: an International Journal (LSIJ) Vol.1, No.1, 2024

Tabi FO, Ogunkunle AO (2007). Spatial variation of some soil physico-chemical properties of an Alfisol in southwestern Nigeria. Niger. J. Soil and Environ. Res., 7:82-91.

Thomas G.W. (1982). Exchangeable cations. In: Page Al, Miller RH, Keeney DR (eds) Methods of soil analysis. Part. American Society of Agronomy –Soil Science Society of American, Madison. 159–166

Tsegaye T. and Hill R.L. 1998. Intensive tillage effects on spatial variability of soil test, plant growth, and nutrient uptake measurements. Soil Sci., v. 163, p. 155-165.

Udoh B.T., Ogunkunle A.O. and Olaleye A.O. (2006) Land suitability evaluation for banana/plantain Musa spp.) cultivation in Akwa Ibom State of Nigeria. J. Res. Agri. 3(3):1-6

Udoh, T.B. Ndaeyo, N.U. and Harold, K.O. (2007) Fertility status and Variability of some soils developed from different parent materials in the humid region of Nigeria, Proceedings of the 31st Annual Conference of Soil Science Society of Nigeria, NAERLS, ABU, Zaria, Nigeria 13th – 17th November 2006, Pages 79-85.

Wang, J., Fu, B., Qiu, Y. and Chen, L. (2001). Soil nutrients in relation to land use and landscape position in the semi-arid small catchment on the loess plateau in China. *Journal of Arid Environments*, 48(4):537-550.

Wezel, A., J.L. Rajor and C. Herbrig, 2000. Influence of shrubs on soil characteristics and their function in Sahelian Agro-ecosystems in semi-arid Niger. J. Arid Environ., 44: 383-398.

Wilding, L.P. 1985. Spatial variability: its documentation, accommodation and implication to soil surveys, In: Soil Spatial Variability: Pudoc, D.R. Nielsen and J. Bouma (eds). Wageningen, Netherlands. p.166-94.

Wilding, L.P. and Drees, L.R. (1978). Spatial variability: a pedologist's viewpoint. In: Diversity of Soils in the Tropics. Soil Sci. SOC. Am., Spec. Publ., 34:l:l-12.

Wilding, L.P. and L.R. Dress. (1983). Spatial variability and pedology, pp. 83-116. *In* L.P. Wilding, N. Smeck and G.F. Hall (eds.). Pedogenesis and Soil Taxonomy. Wageningen. Netherlands.

Yimer, F., Ledin, S. and Abdelkadir, A. (2006). Soil property variations in relation to topographic aspect and vegetation community in the south-eastern highlands of Ethiopia. *Forest Ecology and Management* 232(1–3), 90–99.

Zhang, G., Zhang, P., Peng, S., Chen, Y. and Cao, Y. (2017). The coupling of leaf, litter, and soil nutrients in warm temperate forests in northwestern China. In Scientific reports (p. 11754). Basingstoke, UK: Springer Nature Publishing.