UMYU Scientifica, Vol. 2 NO. 4, December 2023, Pp 001 – 008
https://doi.org/10.56919/usci.2324.001
ISSN: 2955 – 1145 (print); 2955 – 1153 (online)
A periodical of the Faculty of Natural and Applied Sciences, UMYU, Katsina

ORIGINAL RESEARCH ARTICLE

Assessment of Soil Quality for Agro-Diversification in Kaduna State, Nigeria.

Yusuf Idris Garba[1]*, Muhammad Nuraddeen Danjuma[2], Mustapha Zakariya[1].
[1]Department of Environmental Management, Bayero University Kano
[2]Department of Geography, Bayero University Kano.

ABSTRACT

Soil quality is the foundation of productive farming practices. This study assessed soil quality on different land use types to provide recommendations for agro-diversification in Kaduna State. Soil sampling was done along three value chain segments for agro-diversification, namely: (maize, ginger and dairy). In order to have a fair representation and good geographical spread, a total of six clusters were sampled purposively in the value chain segments as follows: dairy processing and production (Zango in Kaduna South LGA and Dorayi in Zaria LGA), maize production processing/production (Biye village in Giwa LGA and Anchau in Kubau LGA) and ginger production and processing (Kwoi in Jaba LGA and Kachia in Kachia LGA). A total of eighteen (18) soil samples were collected at two depths: top (0 – 20 cm) and sub-soil (20 – 40 cm) in the six clusters using an auger. The soil samples were air-dried in situ and packaged in well-labelled cotton bags to aid aeration and prevent soil moisture loss. It was taken to the Centre for Dryland Agriculture laboratory, Bayero University, Kano, for analysis after some in-situ soil temperature and colour investigations. In the laboratory, the soil is bulked, and 500g composite samples were obtained for testing pH, Phosphorus (P), Aluminum (Al), Iron (Fe), Zinc (Zn), Copper (Cu), Manganese (Mn), Sodium (Na), Potassium (K), Calcium (Ca) and Magnesium (Mg), electrical conductivity, total nitrogen, sulphur, and carbon. The findings of the study revealed that the SQI was found to be significantly higher in the ginger production/processing zone as recorded in Kachia ginger production **(**0.94) and Kwoi ginger processing (0.91), while Audi dairy production (0.81) and Zango Dairy processing (0.79) recorded least soil quality index. Therefore, This study recommended that Farmers apply synthetic fertilizer and organic manure to effectively recycle organic amendments on cultivated land.

ARTICLE HISTORY

Received June 02, 2023.
Accepted September 29, 2023.
Published December 30, 2023.

KEYWORDS

soil properties, sustainable land use systems, agricultural productivity, crops

INTRODUCTION

Soil quality is its ability to function within ecosystem boundaries to sustain biological productivity, maintain air and water quality, and support human habitation and health (Karlen *et al.*, 1997). Soil quality has two parts: the intrinsic part covering the inherent capacity of the soil for crop growth and the dynamic part influenced by the soil user or manager (Seybold *et al.*, 1998; Carter, 2002). Soil quality depends on the soil nutrient pools and reserves modulated by land use and several other management factors (Tiwari *et al.*, 2006).

A plethora of works have shown that soil quality is a foundation for agricultural productivity, economic growth, and a healthy environment (Eswaran and Reich, 2001). Assessing soil quality is important for appropriate decision-making regarding sustainable land use systems (Sakbaeva *et al.*, 2012). However, individual soil properties alone may not be sufficient for assessing soil quality (Andrews *et al.*, 2004). An effective tool utilizes the concept of the soil quality index (SQI), which is based on a combination of soil properties that better reflect the status of soil quality compared to individual parameters (Amacher *et al.*, 2007). SQI can be an important tool for planners and decision-makers to combat soil quality degradation by introducing appropriate interventions. It has been noted that SQI can reflect the extent of SQ degradation and thereby give support to suggest appropriate remedial measures such as optimum fertilizer rates and planning of other suitable land management practices considering potentials and constraints of different fields at large scale such as a catchment (Tesfahunegn, 2014**)**.

Based on the understanding that soil quality helps maintain biological productivity and air and water quality on lands, this study evaluates the soil quality of different land use types to provide information for improving agro-diversification in the study area.

Correspondence: Yusuf Idris Garba. Department of Environmental Management, Bayero University Kano. yigarba.em@buk.edu.ng.

How to cite: Garba, Y. I., Danjuma, M. N., & Zakariya, M. (2023). Assessment of Soil Quality for Agro-Diversification in Kaduna State, Nigeria. *UMYU Scientifica*, 2(4), 1 – 8. https://doi.org/10.56919/usci.2324.001

STUDY AREA

This study covered some sections of Kaduna State and is located between Latitude 8°30' and 11°49'N and Longitude 6°00' and 9°00' (Figure 1). The study comprises water bodies, rocky outcrops, vegetation cover, cultivated land, and built-up settlements. The climate of the area is the sub-humid type with more wetness than dryness, which varied markedly from the south to north of the State. The wet season starts in early May and lasts till October. The long dry season commences just after the wet season in October and lasts till February, when another rainfall season begins. In the southern part of the State around Jaba (Sabzuro), the amount of rainfall is above 1100mm/annum, while the north around Ikara and Makarfi bordering Kano State received less than 1000mm/annum. The mean temperature is 25.2°C and varies from 24.4°C to 28.4°C, which can rise to 29°C in April. From the month of November up to January, the mean monthly temperature tends to fail, while maximum temperature tends to rise with declining minimum, creating a wider gap in the temperature range.

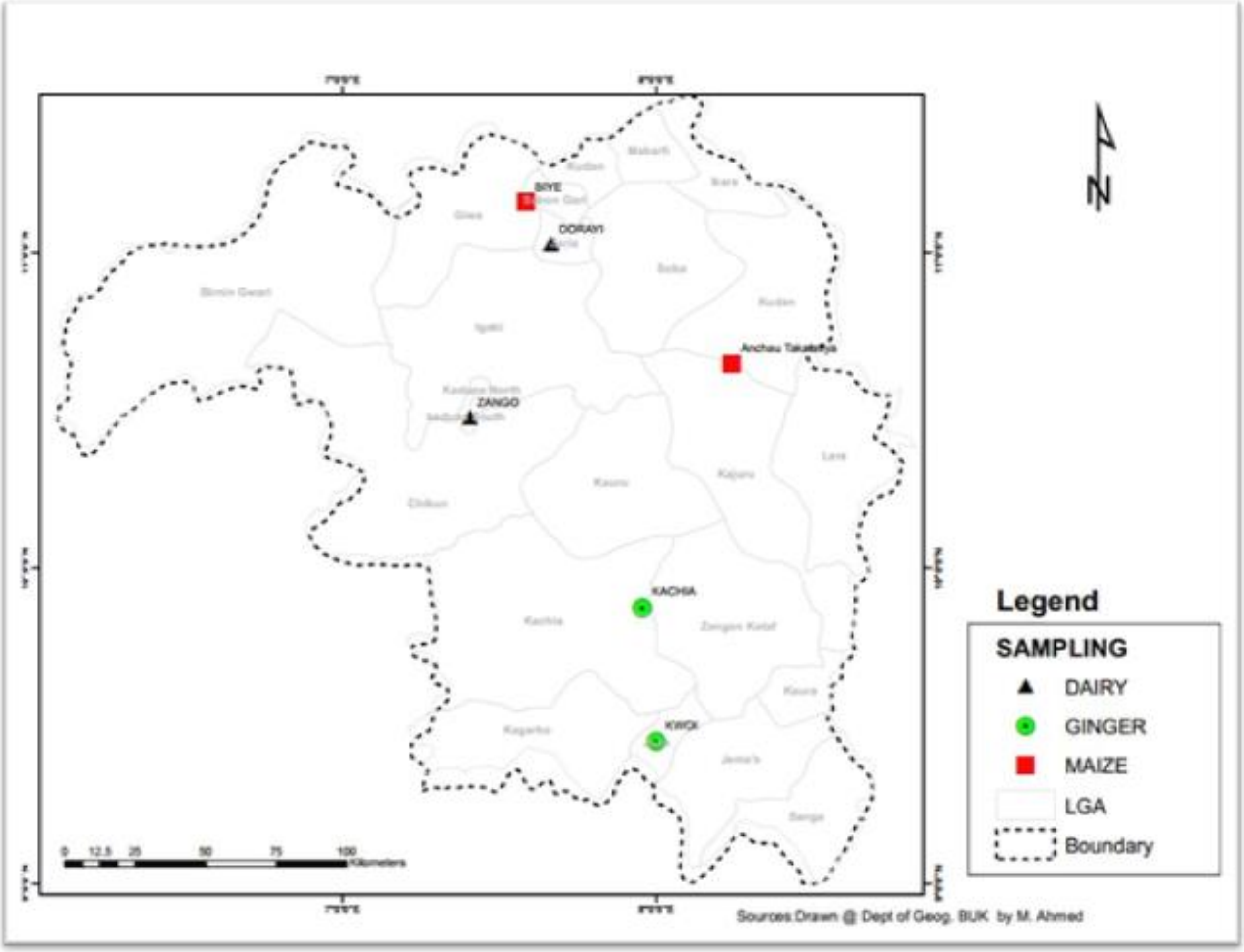

Figure 1: Map of Kaduna Showing the Study Locations

The soil quality is generally good. Using the generic classification of FAO, the soil is made up of loamy to sandy types, which were influenced by drainage patterns of rivers in the state moving westward to the Niger system. The watersheds of the Kaduna River tributaries' entire subsystem modified the soil types.

The study area also hosts a number of animals and plants biodiversity. The north is an open savanna made up of scattered tree species, including Fig (*Ficus sycomorus*), Locust bean (*Parkia biglobosa*), Baobab (*Adansonia digitata*), and African birch (*Anogeissus leiocarpus*), Neem (*Azadirachta indica*), Tamarind (*Tamarindus indica*), African Fan Palm (*Borassus aethiopum*), and Baobab (*Adansonia digitata*). These are mostly found on farms. Also, Chinese banyan (*Ficus thonnnigii*) and Heart-leaved Fig (*Ficus polita*) are commonly found within the settlements. The south, which is wetter, is dominated by rooted floating plants such as Burgu Millet, Bourgou, Hippo grass (*Echinochloa stagnina*), various species of Water lily (*Nyphaeaceae*) and Giant sensitive tree (*Mimosa pigra*) along the channels and banks of major rivers and their tributaries. The area is also significantly modified or destroyed by the removal of woody vegetation, browsing and exploitation for fuel, and cultivation. There are large plantations of exotic species, such as Palm oil trees (*Elaeis guineensis*) and Teak (*Tectonia grandis*) along the riverside in Sabzuro. These trees provide nutrients to the soil of the study area, which supports the production of ginger and maize as well as various agronomic crops in the state. The trees also support the faunal diversity of the area; hence, there are various types of birds, reptiles and mammals. Some birds are water-loving and fly all over the areas for moisture. There are also migrant types, such as the various cranes, *Bubulcus ibis* (Balbela), *ciconia abdimii* (shamuwa) and leptoptilos crumeniferus. Large mammals no longer exist in the northern part of the state except a few primates and Jackal (*Canis mesomelas*), which are occasionally sighted by local residents as reported by key informants. The south is, however, richer in terms of fauna, including spotted Hyena (*crocuta crocuta*) and Gazelle.

MATERIAL AND METHODS

A purposive sampling technique was adopted in sampling communities in each senatorial zone based on their production cluster. A total of six clusters were sampled purposively based on accessibility to the sites, fair representation in the value chain segments (maize, ginger and dairy), and geographical spread. Zango in Kaduna South LGA and Dorayi in Zaria LGA were selected for dairy processing and production (Table 1) Biye village in Giwa LGA and Anchau in Kubau LGA were selected for their prominence in maize production processing/production (Table 2). Kwoi in Jaba LGA and Kachia in Kachia LGA were selected for their prominence in ginger production and processing (Table 3). Safety and security were also considered in selecting all the locations for hitch-free exercise.

Table 1: Sampled Location Dairy Production/Processing

SN	CLUSTERS	Senatorial Zone	LGA	Locations	Value chain segment	Remarks
1	Marjere	Zone 1	Lere	Marjere, Saminaka	Production	
2	Unguwan Madugu	Zone 1	Lere	Unguwan Madugu, Lere		
3	Dorayi	Zone 1	Zaria	Dorayi	Production	Sampled
4	Wucicciri	Zone 1	Zaria	Wucicciri		
5	Dambo	Zone 1	Zaria	Dambo		
6	Tudun Biri	Zone 1		Tudun Biri		
7	Tohu	Zone 1	Sabon gari	Tohu		
8	Rafin Pa	Zone 1	Zaria	Rafin Pa		
9	Rafin Guza	Zone 2	Kaduna North	Rafin Guza		
10	Rigasa	Zone 2	Igabi	Rigasa	Processing	Sampled
11	Zango	Zone 2	Kaduna South	Zango, Tudun Wada Kaduna		
12	Unguwan Nungu	Zone 3	Sanga	Unguwan Nungu	Production	

Table 2: Sampled Location Ginger Production/Processing

SN	Clusters	Senatorial Zone	LGA	Locations	Value chain segment	Remarks
1	Anchau maize	Zone 1	Kubau	Anchau Gari	Production	Sampled
2	Shika maize	Zone 2	Giwa	Biye	Processing	Sampled
3	Ungwan Bawa maize	Zone 1	Lere	Marhaba Ethics & Values MPCS Ltd.	Production	
4		Zone 2			Processing	

Table 3: Sampled Location Ginger Processing/Production

SN	Clusters	Senatorial Zone	LGA	Locations	Value chain segment	Remarks
1	Ham cluster	Zone 3	Jaba	Chori Galadima	Production	
2	Ham cluster	Zone 3	Jaba	Chori Galadima	Processing	Sampled
3	Kachia cluster	Zone 3	Kachia	Kachia	Production	Sampled
4	Kaninkon cluster	Zone 3	Jema'a	kaninkon	Production	
5	Kagarko	Zone 3	Kagarko	kasabere		

In each of the six locations, three farmers' fields were selected for soil sampling based on three major considerations to adequately take care of the study area, namely: 1) adequate coverage of representative and/or probable soil physicochemical and biological characteristics within the study area; 2) capturing the possible effects of existing land use patterns on soil environment; & 3) establishing the potential impact (s) of the operation of the project on the soil environment, including the land use patterns in the area. The sampling locations and their coordinates are as follows (Table 4).

Table 4: Geo-referenced coordinates of the Sampling Locations

Samples (SS)	Locations	Value Chain	Coordinates	
			Latitude (N)	Longitude (E)
SS1	Anchau A	Maize production	11^{0} 02.167′	008^{0} 19.510′
SS2	Anchau B	Maize production	11^{0} 02.129′	008^{0} 19.518′
SS3	Anchau C	Maize production	11^{0} 02.153′	008^{0} 21.011′
SS4	Biye A	Maize processing	11^{0} 09.267′	007^{0} 35.701′
SS5	Biye B	Maize processing	11^{0} 09.218′	007^{0} 35.622′
SS6	Biye C	Maize processing	11^{0} 09.253′	007^{0} 35.712′
SS7	Kachia A	Ginger production	09^{0} 47.641′	007^{0} 58.026′
SS8	Kachia B	Ginger production	09^{0} 47.629′	007^{0} 58.006′
SS9	Kachia C	Ginger production	09^{0} 47.635′	007^{0} 58.064′
SS10	Kwoi A	Ginger processing	09^{0} 28.110′	008^{0} 00.455′
SS11	Kwoi B	Ginger processing	09^{0} 28.109′	008^{0} 00.388′
SS12	Kwoi C	Ginger processing	09^{0} 28.111′	008^{0} 00.467′
SS13	Dorayi A	Dairy production	10^{0} 58.209′	007^{0} 42.644′
SS14	Dorayi B	Dairy production	10^{0} 58.201′	007^{0} 42.639′
SS15	Dorayi C	Dairy production	10^{0} 58.108′	007^{0} 42.658′
SS16	Zango A	Dairy processing	10^{o} 30.153′	007^{0} 24.475′
SS17	Zango B	Dairy processing	10^{o} 30.211′	007^{0} 24.475′
SS18	Zango C	Dairy processing	10^{o} 30.144′	007^{0} 24.475′

A total of eighteen (18) soil sample points were established, and at each sampling point, two (2) soil samples were collected vis surface soil samples and subsurface soil samples at (0 – 20 cm) and (20 – 40 cm) sampling depths with a view to quantifying soil nutrient reserves and soil quality at both levels. These comprise a total of thirty-six surface and subsurface soil samples.

The soil samples were air-dried, bulked together to give a composite sample and collected in well-labelled cotton bags to aid aeration and prevent soil moisture loss. Some in-situ investigations of soil temperature and colour were made. Also, 500g composite soil samples were obtained and taken to the laboratory at the Centre for Dryland Agriculture, Bayero University, Kano, Nigeria, for further investigations of the following parameters: Phosphorus

(P), Aluminum (Al), Iron (Fe), Zinc (Zn), Copper (Cu), Manganese (Mn), Sodium (Na), Potassium (K), Calcium (Ca) and Magnesium (Mg) using Microwave Plasma Atomic Emission Spectrophotometer (4210 MP – AES); autosampler version SPS4. The instrument setting and operational conditions were appropriately carried out in accordance with the manufacturer's specifications. Soil pH was measured in a 1:1 soil/water suspension (Thomas, 1996) using a pH meter (Model 300408.1), which was calibrated using two buffer solutions, pH 4 and pH 7. Electrical Conductivity was measured using a conductivity meter, and texture was analyzed by the hydrometer method as described by (Gee and Bauder, 1986; Eno *et al.*, 2009). Soil colour was determined using the Munsell colour chart. The organic carbon content of the soils was determined by the modified Walkley-Black method, as described by Nelson and Sommers (1982). Total nitrogen, sulphur, and carbon were determined using a CHNS analyzer.

For the assessment of soil quality, the soil quality index (SQI) was computed based on the soil management assessment framework (SMAF). It includes three steps: indicator selection, indicator interpretation, and integration into an index. **i) Indicator Selection** - The potential soil quality indicators were selected on the basis of the management goal of increasing productivity and protecting the environment by taking into consideration the ease and cost of sampling and laboratory analysis; **ii) Indicator Interpretation** - This step involved the transformation of the observed indicator value using a non-linear scoring curve into the unit less values from 0 to 1 using SMAF interpretation (version 2013-04) so that the scores could be combined to form a single value. The general relationship between a given indicator and the soil function dictates the shape of an indicator's scoring curve. Some general shapes include more-is-better, less-is-better, and mid-point-optima; **iii) Integration into an Index -** This step was accomplished by summing the scores for each indicator and dividing by the total number of indicators as in Eq 1.

Soil Quality is represented as $SQI = \frac{\sum_{n-I} \mathrm{Si}}{n}$ eqn (1)

A SQI value close to 1 refers to the best functioning soil, while a relatively lower value refers to degraded soil. For the selected indicators, the observed value was transformed into unitless scores that range from 0 to 1 using non-linear scoring curves in line with (Andrews *et al.,* 2004) & (Wienhold *et al.*, 2009)

RESULTS AND DISCUSSIONS

This section showed the findings of this study and discussion as follows:

Soil Characteristics on the Different Land Use Types

The distribution of the soils in the area is generally influenced by geological substrate and topographic positions. Fourteen important soil quality indicators were investigated under the land use management regimes **(**Maize, Ginger and Dairy**)**. The ranges and means of soil properties of the representative sites were nuanced (Table 5). The texture of the soils common to maize production/ processing clusters, i.e. Anchau Takalafiya and Biye Shika, was sandy loam. Sandy clay loam was common to the ginger production/processing clusters, while in the dairy clusters, Audi of Dorayi was occupied by sandy loam and Zango dairy processing was occupied by clay loam. The coarse textured surface characteristic is a common feature associated with soils formed from basement complex rocks (Ezenwa and Esu, 1999). This may be attributed to erosion of fine particles by surface runoff down the slope from the crested position and their illuviation into the subsoils (Ande, 2010; Maniyunda, 2012). The soils were found to be acidic in all the land use types (pH < 7). However, the different land uses have a slight pH variation (Table 5). Kachia and Kwoi soils were more acidic than other areas, possibly due to the higher rainfall in these areas. The soil organic carbon was found to be low among all the different land uses, with the lowest values recorded from the Anchau and Biye maize production/processing zones and a higher value recorded from the Zango Dairy production/processing site. The low organic carbon recorded may be attributed to extensive farming replacing trees and other vegetative covers. Cutting trees and clearing parcels of land impacts soil quality degradation and aridity, namely loss of organic matter and nutrients, soil acidification, and compaction of surface soil, especially if coupled with poor management and intensive farming practices. The effective cation exchange capacity (ECEC) of the soils was low, ECEC (<6.0 Cmol (+) kg^{-1}).

The low ECEC level implies that the soils were dominated by low-activity clays and sesquioxides (Tan, 2000) and low organic colloidal fractions, suggesting the soils would be susceptible to leaching (Shehu *et al.*, 2015). This also indicates that the soils at their natural pH levels remain low in CEC, indicating a low capacity of the soils to retain nutrients (Sharu *et al.*, 2013). The total nitrogen values of the soils in the area changed irregularly with depth, which could be attributed to the influence of continuous cultivation, a common practice in the area that is accompanied by nearly crop residue removal. The exchangeable bases of the soils are generally low. Similar results were reported by Raji *et al.*, (2011). Calcium and magnesium are the predominant basic cations in the soils. Similar observations have been made in the past for West African soils in general (Kowal and Knabe, 1972). It is also in tune with the findings of Esu (1991) and Maniyunda (2012).

Table 5: Soil Physical and Chemical Properties in the Study Location

Soil Quality Indicators	Land use					
	Maize Production/Processing		Ginger Production/Processing		Dairy Production/Processing	
	Anchau	**Biye**	**Kachia**	**Kwoi**	**Audi**	**Zango**
Texture	Sandy Loam	Sandy Loam	Sandy Clay Loam	Sandy Clay Loam	Sandy Loam	Clay Loam
pH						
Range	6.0 -5.83	6.52-6.06	5.6-5.32	5.51-5.23	5.78-5.6	6.2-5.91
Mean	5.91	6.29	5.46	5.37	5.69	6.04
Organic Carbon (%)						
Range	0.53-0.49	0.47-0.34	0.8-0.62	0.61-0.43	0.59-0.54	0.64-0.59
Mean	0.51	0.41	0.71	0.52	0.57	0.62
Total Nitrogen (%)						
Range	0.05-0.04	0.08-0.04	0.07-0.04	0.07-0.05	0.07-0.03	0.05-0.04
Mean	0.05	0.06	0.05	0.06	0.05	0.05
Phosphorus (mg/kg)						
Range	6.12-4.82	2.89-2.37	3.04-0.58	3.93-2.3	4.33-2.04	3.21-2.04
Mean	5.47	2.63	1.81	3.12	3.19	2.45
ECEC (cmol(+)/kg)						
Range	3.08-2.68	3.38-2.76	3.22-2.22	2.97-2.8	2.8-2.16	5.02-4.36
Mean	2.88	3.05	2.72	2.89	2.48	4.59
Exchangeable Ca (cmol(+)/kg)						
Range	1.86-1.74	2.2-1.77	2.25-1.53	2.03-1.99	1.87-1.34	3.84-3.21
Mean	1.80	1.99	1.89	2.01	1.61	3.46
Exchangeable Mg (cmol(+)/kg)						
Range	0.89-0.58	0.94-0.58	0.7-0.41	0.48-0.43	0.72-0.6	0.72-0.63
Mean	0.73	0.76	0.56	0.46	0.66	0.68
Exchangeable K (cmol(+)/kg)						
Range	0.12-0.09	0.15-0.09	018-0.17	0.2-0.15	0.13-0.11	0.24-0.19
Mean	0.11	0.12	0.17	0.18	0.12	0.21
Exchangeable Na (cmol(+)/kg)						
Range	0.10-0.08	0.08-0.07	0.09-0.07	0.09-0.08	0.09-0.08	0.09-0.08
Mean	0.09	0.08	0.08	0.09	0.08	0.08
Available Cu (mg/kg)						
Range	1.98-1.54	2.55-0.96	2.14-1.97	2.64-2.2	3.37-2.19	1.76-1.22
Mean	1.76	1.76	2.06	2.42	2.78	1.54
Available Mn (mg/kg)						
Range	20.64-16.4	37.54-22.03	17.64-12.71	25.82-25.49	35.25-23.26	64.02-37.33
Mean	18.52	29.78	15.18	25.66	29.26	51.16
Available Fe (mg/kg)						
Range	199.01-139.85	152.98-135.84	113.45-98.71	96.78-93.5	130.53-112.21	91.21-77.31
Mean	169.43	144.41	106.08	95.14	121.37	84.81
Available Zn (mg/kg)						
Range	5.96-4.53	27.34-7.13	1.72-0.25	6.47-1.56	7.13-3.39	2.36-1.21
Mean	5.25	17.24	0.99	4.02	5.26	1.85

Soil Quality Index

Soil Quality Index (SQI) was calculated to evaluate soil quality on the different land use types in study locations using an index on the basis of the soil management assessment framework.

Table 6: Soil Quality Index for the Different Land Use Types

Study Locations	Clusters/Land Use Type	SQI
Anchau Takalafiya	Anchau (Maize production)	0.89
Biye, Shika Cluster	Shika (Maize processing)	0.85
Kachia	Kachia (Ginger production)	0.94
Kwoi	Ham (Ginger processing)	0.91
Audi, Dorayi Cluster	Zaria (Diary production)	0.81
Zango, T/Wada	Zango(Dairy processing)	0.79

The SQI was found to be significantly higher in the ginger production/processing zone, with the highest value recorded from Kachia ginger production (0.94) and Kwoi ginger processing (0.91), while Audi dairy production (0.81) and Zango Dairy processing (0.79) recorded least soil quality index (Table 6). The higher SQI recorded from the ginger production/processing zone may be due to higher vegetative cover and the mulching practised by the ginger farmers, which might protect the soils from a high rate of soil erosion and leaching of minerals.

CONCLUSION

As expected, the soil quality of the study area is relatively high, but its ranges and means were nuanced. Owing to different farming systems and climate, this study concluded that study locations in the southern part of the state point to a higher index and obviously can provide more services in the face of natural and human-induced disturbance.

RECOMMENDATION

The major parameters that affected the SQI among the different land use types were the soil texture, organic carbon content and effective cation exchange capacity (ECEC). This study recommended that:

> Farmers should apply both synthetic fertilizer and organic manure for effective recycling of organic amendments on cultivated land and to manage the major parameters that affected the SQI among the different land use types, namely soil texture, organic carbon content and cation exchange capacity (ECEC)

REFERENCES

Amacher M.C., O'Neill, K.P. & Perry, C.H. (2007). Soil vital signs: A new Soil Quality Index (SQI) for assessing forest soil health. USDA Forest Service Res. Pap., RMRS-RP-65WWW, 2007. **[Crossref]**

Ande, O.T. (2010). Morphogenetic Characterization of Soils Formed from Basement Complex Rock in the Humid Tropical Rainforest of Nigeria. *Journal of Soil Science and Environmental Management*, 1(6): 122126.

Andrews S.S., Karlen D.L. & Cambardella, C.A. (2004). The Soil Management Assessment Framework. *Soil Science Society of America Journal*, 68: 1945-1962.; **[Crossref]**

Carter, M.R. (2002). Soil Quality for Sustainable Land Management: Organic Matter and Aggregation Interactions that Maintain Soil Functions. Agronomy Journal, 94: 38-47. **[Crossref]**

Denboba, M.A. (2005). Forest Conversion, Soil Degradation, Farmers' Perception Nexus: Implications for Sustainable Land Use in the Southwest of Ethiopia, Cuvillier Verlag.

Eno, J.U., Trenchard, O.I., Joseph, A.D., Anthony, O.A., & Ivara, E.E. (2009). Manual of Soil, Plant and Water Analysis. Sibon Book Ltd, Lagos.

Esu, I.E. (1991). Detailed soil survey of NIHORT farm at Bunkure Kano state, Nigeria. Institute for Agricultural Research Samaru, Zaria, Nigeria.

Eswaran H., Lal, R. & Reich, P. (2001). Land Degradation: an overview. In: Bridges, E.M. et al. (eds.).Responses to Land degradation, Enfield, NH, USA: Science Publishers.

Ezenwa, M.I.S. & Esu, I.E. (1999). A Pedological Study of Soils Derived from Basement Complex Rocks in the Guinea Savanna Area of Nigeria. *Samaru Journal of Agricultural Research*, 15:35-50.

Gee, G.W. & Bauder, J.W. (1986). Particle Soil Analysis. In: Klute, A. Methods for Soil Analysis. Part 1: Physical and Mineralogical Methods (pp. 383-411). Madison, Wisconsin, USA: Soil Science Society of America. American Society of Agronomy. **[Crossref]**

Karlen, M., Mausbach, D., Doran, J., Cline, R. Harris, R. & Schuman, G. (1997). Soil Quality: a Concept, Definition, and Framework for Evaluation (a guest editorial). *Soil Science Society of America Journal*, 61: 4-10. **[Crossref]**

Kowal, J.M. and Knabe, D.T. (1972) An Agro-climatological Atlas of the Northern State of Nigeria. ABU Press, Zaria, Nigeria.

Lal R., Iivari T. & Kimble, J.M. (2004). Soil Degradation in the United States: Extent, Severity, and Trends, CRC Press. [**Crossref**]

Maniyunda, L.M. (2012). *Pedogenesis of A Lithosequence in the Northern Guinea Savanna of Kaduna State, Nigeria.* Unpublished PhD, Thesis. Department of Soil Science, Ahmadu Bello University Zaria, Nigeria.

Nelson D.W. and Sommers, I.E. (1982) A rapid and Accurate Procedure for Estimation of Organic Carbon in Soils. *Proceedings of Indian Academy of Science*, 84:456 - 82.

Raji, B.A., Malgwi, W.B., Berding, F.R. & Chude, V.O. (2011). Integrating Indigenous Knowledge and Soil Science Approaches to Detailed Soil Survey in Kaduna State, Nigeria. *Journal of Soil Science and Environmental Management*, 2(3): 66-73

Sakbaeva, Z., Acosta-Martínez, V., Moore-Kucera, J., Hudnall, W. & Nuridin, K. (2012). Interactions of Soil Order and Land Use Management on Soil Properties in the Kukart Watershed, Kyrgyzstan. *Applied and Environmental Soil Science*, 2012:1-11 [**Crossref**]

Seybold, C., Mausbach, M., Karlen, D. & Rogers, H. (1998). Quantification of Soil Quality. In: Lal, R. (eds). *Soil Processes and the Carbon Cycle*. Boca Raton, FL: CRC Press.

Sharu, M.B., Yakubu, M., Noma, S.S. & Tsafe, A.I. (2013). Characterization and Classification of Soils on an Agricultural Landscape in Dingyadi District, Sokoto State, Nigeria. *Nigerian Journal of Basic and Applied Science*, 21(2): 137-147 DOI: [**Crossref**]

Shehu, B.M., Jibrin, J.M. & Samndi, A.M. (2015). Fertility Status of Selected Soils in the Sudan Savanna Biome of Northern Nigeria. *International Journal of Soil Science*, 10 (2): 74-83, 2015 ISSN 1816-4978/ [**Crossref**]

Tan, K.H. (2000). *Environmental Soil Science.* 2nd Edn., CRC Press, Boca Raton, FL.

Teshahunegn, G.B. (2014). Soil Quality Assessment Strategies for Evaluating Soil Degradation in Northern Ethiopia. *Applied and Environmental Soil Science*, 1:14. [**Crossref**]

Thomas, G.W. (1996). Soil pH and Soil Acidity. In: Sparks, D.L.. Methods for Soil Analysis. Part 3: Chemical methods (pp. 475-490). Madison, Wisconsin, USA: Soil Science Society of America. American Society of Agronomy. [**Crossref**]

Tiwari K.R., Sitaula, B.K., Borresen, T. & Bajracharya, R.M. (2006). An Assessment of Soil Quality in Pokhare Khola Watershed of the Middle Mountains in Nepal. *Journal of Food Agriculture and Environment*, 4: 276-283.

Wienhold B. J., Karlen D., Andrews, S. & Stott, D. (2009). Protocol for Indicator Scoring in the Soil Management Assessment Framework (SMAF). *Renewable Agriculture and Food Systems*, 24: 260-266. [**Crossref**]