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Soil Quality Evaluation in Agricultural Soils of Funtua Area, Katsina State, Northwestern, Nigeria
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ABSTRACT

Soil quality has become an important environmental issue all over the world. Soil quality of agricultural soils in Funtua area of Katsina state was evaluated. A total of twelve soil samples were collected and analyzed for pH, electrical conductivity, organic carbon, organic matter, total nitrogen, phosphorus, cadmium, chromium, lead, iron, manganese and zinc. The heavy metals were analyzed using atomic absorption spectrometry (AAS). Geo-accumulation index and contamination factor were utilized in the analysis. Descriptive statistics of range, mean and standard deviation were employed in summarizing the collected data. The result of soil properties revealed that, all studied parameters were found to be low with EC having the highest mean concentration (215.50) and OC with low content (2.212%). From the result of heavy metals, Cr has the highest concentration with the mean of 0.251mg/kg and Pb having the lowest value of 0.087mg/kg, all analyzed metals were found below the limit in agricultural soils. Result of heavy metals I-geo values of all samples indicate that the soil unpolluted, the relative distributions of the contamination factor among the samples were described as Cd > Cr > Mn > Zn > Pb > Fe. For all soil samples the heavy metal Cd has a CF values range of 3.3333-20.00, indicating that the agricultural soil samples are very highly contaminated with Cd followed by Cr ranges from 0.011-2.000, indicating moderately contaminated. In conclusion, based on analyzed parameters the agricultural soil was unpolluted and has low concentrations except Cd and Cr. It is recommended that continuous monitoring of heavy metals should be taken into consideration.

Keywords: Soil quality, Agricultural soil, Geo-accumulation index, Contamination factor, Funtua.

1.0 INTRODUCTION

Agriculture is considered to be the major human activities in many developing nations that modified the landforms, water resources and biogeochemical cycles (Rodrigo-Comino *et al.*, 2018). It is also a key driver of the land degradation processes (and desertification) and within the processes that are responsible for the soil pollution (Kumar, *et al.*, 2019; Cermansky, 2015). Soil is among the natural component of the earth serving a variety of important roles in our society including food production. As a result of rapid industrialization and agriculture during the last decades in many parts of the globe, the soil compartment is receiving a substantial amount of pollutants from different sources including heavy metals (El-Madani, & Hacht, 2017; Gupta, *et al.*, 2016).

However, the major sources of heavy metal contamination in agricultural soils include the impact from the city, smelting minerals, waste

treatment (such as landfill, etc.), sewage sludge, automobile exhaust, fertilizers and pesticides, etc (Zheng, *et al.*, 2010; Montagne *et al.*, 2007). Anthropogenic inputs in agricultural soils that contribute to an increase of the content of some toxic heavy metals have been earlier reported including the excessive usage of agrochemicals and manure (Lu *et al.*, 2012; Hani and Pazira, 2011). Studies also indicated that considerable amounts of toxic metals arising from human activities are accumulated in soil (Ideriah, *et al.*, 2011). Although fertilizers, pesticides and mulch are important agricultural inputs for providing adequate nutrients and ensuring successful harvests, long-term repeated application of fertilizers and metal-containing pesticides and fungicides can gradually resulted in the contamination of the soil (Kelepertzis, 2014; Jiao *et al.*, 2012).

In the past, soil contamination was not considered as important as air and water pollution, because soil

contamination was often with wide range and was more difficult to be controlled and governed than air and water pollution (Su, *et al.*, 2014). The problem of high concentrations of heavy metals, especially in agricultural soils, creates a global environmental issue due to the crucial importance of food production and security (Kowalska, *et al.*, 2018; Chen *et al.* 2015; Kelepertzis 2014). Heavy metal pollution is visible in farmland located in the vicinity of pollution sources, but also occurs outside these areas as well (Al-Anbari, *et al.*, 2015). Consuming crops such as maize, rice and soybeans grown on heavy metal contaminated soils greatly increases the potential risk of food safety and health to human. Basically, there are several heavy metals that are minor needed by plants such as Cu and Zn. But, if the number had exceeded the threshold, this type of heavy metal becomes very dangerous when absorbed by the plants. Heavy metal also will not decompose on its own, so it would be very dangerous if it is continuously accumulated (Uddin, *et al.*, 2019; Husnizar, & Yuliansyah, 2018). Some trace metals are very harmful because of their non-biodegradable nature, long biological half-lives and their potential to accumulate in different body parts (Oti Wilberforce, and Nwabue, 2013).

Studies in Nigeria (Abulude, 2005; Awode, *et al.*, 2008; Uwah, *et al.*, 2009; Nwajei, *et al.*, 2012) have reported that there is high concentration of heavy metals in soils as well as plants. Yaradua, *et al.*, (2020) reported that Fe concentration in agricultural soils is high several times than other studies in Katsina state. Results of scientific research also revealed that even in low concentrations, the combined effect of persistent synthetic chemicals such as pesticides causes suppression of immune response and hypersensitivity to chemical agents. Causes of breast cancer, reduced sperm count, male sterility etc are well documented as a result of pesticide ingestion (Fianko, *et al.*, 2011). Different methods like geo-accumulation index (Igeo), contamination factor (CF), enrichment factor (EF) and ecological risk index (RI), etc., have been applied by different researchers across the globe to widely assess the quality of soils (Heidari, *et al.*, 2019; Tian, *et al.*, 2017). However, the quality of soil in agricultural land in most part of Katsina state northern Nigeria has received less attention than it should have. The

main objective in this research was to evaluate the quality of soil in agricultural land in Funtua area of Katsina state and determine the current state of knowledge of contamination by heavy metals.

2.0 MATERIALS AND METHOD(S)

2.1 Study Site Description

The current research work was done in Funtua local government area of Katsina state. It is located in the extreme southern part of the state, at about 197km away from the state capital. It is found between latitudes 11⁰19'59''N and 11⁰42'58''N, and longitudes 7⁰14'42''E and 7⁰29'15''E, (Figure 1). It has a total land mass of approximately 448km². The area lies in the tropical continental climatic belt (wet and dry), with two main seasons; a rainy season, which is irregular, and runs from May to October, characterized by short intense rains, and a prolonged dry season that stretches from October to May. The annual rainfall ranges between 900mm to 1,200mm, with a single maximum in July and August. On the average, August is the wettest month in which highest number of rainstorms is recorded. The area experiences a maximum temperature of 36⁰C-38⁰C in the month of March and April, and a minimum of 14⁰C-19⁰C in the month of December and January with the mean monthly temperature of 24⁰C to 31⁰C (Hazo, *et al.*, 2019). Relative humidity is highest during the rainy season with an average value of about 80%. It drops rapidly after the end of the rainy season in October, reaching a low of less than 20% during the Harmattan period in December and January up to the month of April (Maiwada and Hassan, 2019).

Relief of the study area is composed of undulating plain (part of the high plains of Hausa-land) which generally rises up to about 600 – 700m above sea level, intersected by series of hills, which are important hydrological centers that control drainage system of the area, which is dominated by mostly seasonal rivers and streams (Hazo, *et al.*, 2019). The soil type of the area is ferruginous tropical brown and reddish-brown soils derived from basement complex rock. The Aeolian drift materials are mostly derived from the Cretaceous sandstones lying in the area, and the parent material underlying the study area are composed of unconsolidated sands (Maiwada and Hassan 2019). The area lies in the Sudan savanna vegetation belt.

This reflects the amount and duration of the rainfall received in the area. With trees such as shea tree (*Vitellaria paradoxa*), tamarind (*Tamarindus indica*), Neem (*Azadirachta Indica*) e.t.c. Shrubs such as young dum palm (*Hyphaene thebaica*) and grasses such as *Digitaria debilis*; *D. velutina*, scent-leaf (*Ocimum basilicum*), spiderwort (*Commehna nudiflora*) e.t.c. The major land use in the area are

residential, crops cultivation (mostly rain-fed) and to some extent irrigation along rivers, streams and reservoirs, animal rearing (both intensive and extensive systems) Other occupations of the people include trading, as well as fishing along rivers, streams and reservoirs (Maiwada and Hassan, 2018).

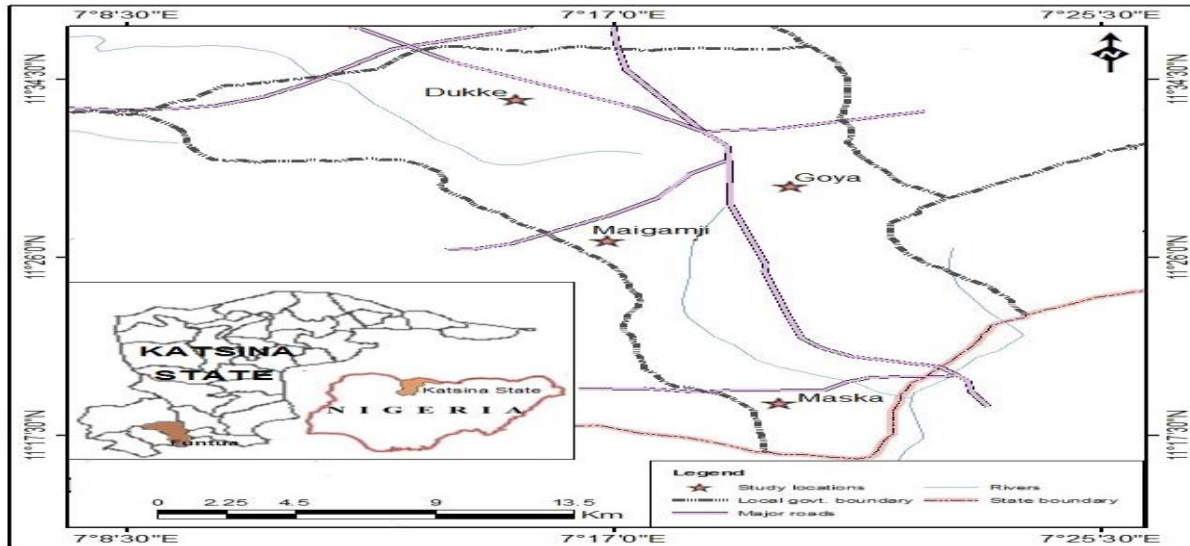


Figure 1: Map of Funtua local government showing study area

2.2 Soil Sample Collection and Processing

Stratified random sampling technique was used. Soil samples were collected from top soil (0 – 15cm) with the aid of cylindrical plastic auger at four political wards (Maigamji, Maska, Dikke and Goya). These wards were selected for the considerable engagement in rain-fed farming activity and on the basis of spatial locations of the areas. At each sampling location, three subsamples were randomly collected at different points, a total of twelve samples were collected, stored in polyethylene bags and taken to soil and water laboratory. All samples were stored at room temperature for pre-treatment and analyses.

2.3 Sample Preparation and Digestion

Samples were air-dried at room temperature for a period of four days and later oven-dried at 100°C for three hours to obtain a constant weight. They were then ground using agate mortar and pestle and sieved using 2mm mesh standard sieve. The

resulting powders were then digested with concentrated 4MHN03 on a hot plate for 3 hours, then evaporated and diluted with 50 mL of distilled water to determine the concentration of Pb, Cd, Mn, Zn, Cr and Fe, with atomic absorption spectrophotometer (AAS BRANDMODEL VGP 210). Soil pH, electrical conductivity, organic carbon, total nitrogen, available phosphorus and soil organic matter content was also determined in the laboratory.

2.4 Contamination Level Using Index Analysis

2.4.1 Geo-accumulation Index (I_{geo})

Geo-accumulation index (I_{geo}) is widely used to estimate the potential risk of metals derived from anthropogenic activities. It was first proposed by Muller (1969). I_{geo} is calculated using following equation:

$$I_{geo} = \log_2 \left[\frac{C_n}{1.5B_n} \right]$$

Where:

C_n = presents concentration of the element in the enriched samples (mg/kg)

B_n = denotes background value of heavy metals (mg/kg)

The factor 1.5 is introduced to minimize the effect of possible variations in the background values which may be attributed to lithologic variations in the soils (Stoffers, *et al.*, 1986). The descriptive classes for increasing I-geo value was proposed by Muller (1969) as follows: the value of soil quality is considered as unpolluted (Igeo is ≤ 0 , class 0); from unpolluted to moderately polluted (Igeo is 0 - 1, class 1); moderately polluted (Igeo is 1 - 2, class 2); from moderately to strongly polluted (Igeo is 2 - 3, class 3); Strongly polluted (Igeo is 3 - 4, class 4); from strongly to extremely polluted (Igeo is 4 - 5, class 5) and Extremely polluted (Igeo is >6 , class 6).

3.0 RESULTS AND DISCUSSION

3.1 Descriptive statistics of soil properties

The descriptive analysis of all analyzed parameters are presented in Table 1. Soil properties of all samples reveals that organic carbon (OC) has the lowest concentration, ranges from 1.34-2.69 % with a mean value of 2.212. Similar study by Salisu and Umar, (2020); Mustapha *et al* (2011) reported low organic carbon content. They pointed out that, most savannah regions of Nigeria are characterized by low organic carbon content. Also Aydinalp (2010) attributed the low organic content to the prevailing dry conditions, where the biomass production is low and rate of mineralization is high. The low level of organic carbon is not surprising because of the continuous of intensive cropping without much addition of organic matter inform of crop residue and manures. Low organic matter content indicating that the low soil fertility and some reasonable amount of organic matter should be improved in the area as part of the future management practices.

EC recorded the highest concentration which ranges from 171-233 with the mean value of 215.50. Although soil EC does not directly affect plant growth, but it has been used as an indirect indicator of the amount of nutrients available for plant uptake and salinity levels (Esmaeili, *et al.*,

2.4.2 Contamination Factor

Contamination Factor (CF) was used to determine the contamination status of the agricultural soil samples. CF was calculated according to the equation described below (Pekey *et al.*, 2004):

$$C = M_c / B_c$$

Where M_c Measured concentration of the metal and B_c is the background concentration of the same metal. Four contamination categories are documented on the basis of the contamination factor (Hakanson, 1980). $CF < 1$ low contamination; $1 \leq CF \leq 3$ moderate contamination; $3 \leq CF < 6$ considerable contamination; $CF > 6$ very high contamination.

2.5 Statistical analysis

Analyzed data were subjected to descriptive statistics of minimum, maximum and mean using SPSS version 20.

2014; Smith and Doran, 1996). The most fundamental soil fertility is the appropriate values of soil pH and soil organic matter contents. In general, a value of 7.0 for soil pH is regarded as optimum for nutrient cycling (Smith and Doran 1996) and availability of soil nutrients (Brady 1974). However, the pH values of all samples in this study were all lower than 7.0. It is therefore possible for the immobile nutrient P to increase during crop growing in the area. But mobility and retention of heavy metals in soils are highly influence by high soil pH and cationic elements tends to be more mobile in low soil pH (Esmaeili, *et al.*, 2014). Similar observation was reported by Lui, *et al.*, (2014).

Total Nitrogen in this study was found to be low ranges from 6.65 to 23.20 with a mean value of 16.133%. The low level of the total nitrogen obtained in the studied soil could be attributed to the low level of organic matter as well as presence of leaching. The mean value of total nitrogen reported in this study is higher than that reported by Ibrahim and Rumah, 2014; Ibrahim and Maiwada, (2014) for small farm holding in Jibia and Kaita Katsina state.

The status of available phosphorus in the studied soil is low, ranges from 4.8 to 8.9 with the mean

value of 6.35. The low level of phosphorus could be due to less concentration of phosphorus in parent materials of most soils in the savannah regions. Sufficient amount of phosphorus application for high yield of crops is needed in this areas. This study is coincide with the findings of Salisu and Umar, (2020)

The level of organic matter in the studied soil was found to be low ranging from 2.30 to 4.64 with the average value of 3.813. Soil organic matter (SOM) influences heavy metal absorption in soil. This effect is probably due to the cation exchange capacity of organic materials (Martin and Kaplan,

1998). Likely reasons for the low percentage value for organic matter content may be the high number and intensity in application of chemical fertilizer. This result of organic matter are consistent with those reported by Ibrahim and Rumah, (2014) for soil quality analyses under small farm holding in northern part of Katsina. Also Esmaeili, *et al.*, (2014) reported mean value of organic matter slightly higher than that our study. From the result, it indicates that all analyzed parameters fell below the range of indicators as compared with the standard range of soil quality indicators based on Harris, *et al.* (1996).

Table 1: Statistical summary of some soil properties

Soil properties	Agricultural soil samples ($n = 12$)		
	Range	Mean	St. Dev. ^a
pH	4.5-6.8	5.66	0.619
EC ($\mu\text{S}/\text{cm}$)	171-233	215.50	17.165
Organic Carbon (%)	1.34-2.69	2.212	0.366
Organic Matter (%)	2.30-4.64	3.813	0.632
Total Nitrogen (%)	6.65-23.20	16.133	5.989
Available Phosphorus mg/kg	4.8-8.9	6.35	1.320

^a Standard deviation

Regarding heavy metals concentration in agricultural soil, the statistical summary of the measured heavy metals concentration in the study area is shown in Table 2. Pb has the lowest concentration ranges from 0.01 to 0.22 mg/kg with the mean value of 0.087 mg/kg, while Cr having the highest concentration ranges from 0.25 to 0.50 mg/kg with the mean value of 0.251 mg/kg. Cd ranges between 0.10 and 0.60 mg/kg with the mean value of 0.233, Mn ranges from 0.10 to 0.40 with mean value of 0.233, Zn ranging from 0.11 to 0.28 with the mean value of 0.171 and Fe ranging from 0.07 to 0.33 with the mean value of 0.184. The high concentration of Cr could be attributed to the increase inputs from anthropogenic emissions. The concentration values for the heavy metals evaluated is in the decreasing order Pb > Zn > Fe > Cd > Mn

> Cr. Pb, Mn, Zn and Fe concentration in this study is lower than that reported by Yaradua, *et al.*, (2020) in agricultural soils of Katsina. Cr concentration in this study is slightly similar with that reported by Ahaneku and Sadiq, (2014) for agricultural soils in Bosso, Chanchaga, Gidan Kwano, Lafia metropolis, Maiduguri metropolis and the city of Owerri all in Nigeria. Mn and Cr content reported in this study is much lower than that described for agricultural and background soils of Isfahan, Iran (Esmaeili, *et al.*, 2014). Similarly Opaluwa *et al.* (2012) and Abdullateef *et al.* (2014) reported Cd content several times higher than that reported in this study. Further contrary to this study was that of Antibachi, *et al.*, (2012) who reported high Cr, Mn, Zn, Pb and Fe content in agricultural soils of the Mouriki-Thiva area (Central Greece).

Table 2: Statistical summary of heavy metals samples from agricultural soils

Heavy metals	Agricultural soil samples ($n = 12$)			In agricultural soils ^b
	Range	Mean	St. Dev. ^a	
Pb (Mg/kg)	0.01-0.22	0.087	0.064	10-30
Cr (Mg/kg)	0.25-0.50	0.251	0.186	70-100
Cd (Mg/kg)	0.10-0.60	0.233	0.161	0.2-1.0
Mn (Mg/kg)	0.10-0.40	0.233	0.075	
Zn (Mg/kg)	0.11-0.28	0.171	0.051	50

Fe (Mg/kg)	0.07-0.33	0.184	0.088
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^a Standard deviation

^b Common value in agricultural soil (Alloway, 1990)

3.2 Quantification of pollution level in agricultural soils

The pollution level was determined by employing geo-accumulation index (I-geo) and contamination factor (CF) Table 3 and 4 presented the result. From

the results of heavy metals I-geo values obtained (table 3), it revealed that, all soil samples falls within (class of 0), based on Muller's classification, the agricultural soil were unpolluted. This is contrary to the findings of Yaradua et al., (2020).

Table 3: Heavy metals geo- accumulation index of agricultural soils sample

Sample site	Geo-accumulation Index (I-geo)					
	Pb	Cr	Cd	Mn	Zn	Fe
Maska 1	-0.589	0.036	0.347	-0.290	-0.798	-2.268
Maska 2	-0.492	-0.140	0.648	-0.466	-1.002	-2.097
Maska 3	-0.890	-0.140	1.125	-0.765	-0.701	-2.276
Maigamji 1	-1.191	0.036	0.949	-0.290	-0.856	-2.149
Maiganji 2	-0.714	-0.140	0.347	-0.466	-0.923	-2.775
Maiganji 3	-1.201	-0.140	0.347	-0.466	-0.923	-2.745
Goya 1	-1.191	-0.140	0.397	-0.767	-1.099	-2.568
Goya 2	-0.890	-0.441	0.824	-0.466	-1.099	-2.744
Goya 3	-1.191	0.036	0.624	-0.369	-1.099	-2.276
Dikke 1	-0.714	-0.061	0.678	-0.466	-0.923	-2.257
Dikke 2	-1.191	-0.140	0.347	-0.466	-0.798	-2.276
Dikke 3	-0.681	-0.140	0.648	0.369	-1.099	-2.357

Table 4 presented the result of heavy metals contamination factor. From the table, the relative distributions of the contamination factor among the samples were described as Cd > Cr > Mn > Zn > Pb > Fe. Soils have been used as environmental indicators, and this ability to identify heavy metal contamination sources and monitor contaminants is also well documented. Thus, the accumulation of metals in the soils is strongly controlled by the nature of the substrate as well as the physicochemical conditions controlling dissolution

and precipitation (Yaradua, *et al.*, 2020; Venkatramanan *et al.* 2012). For all soil samples the heavy metal Cd has a CF values range of 3.3333-20.00, indicating that the agricultural soil samples are very highly contaminated with Cd. Cr contamination values ranges from 0.011-2.000, indicating that the agricultural soil samples were also moderately contaminated. The remaining heavy metals (Pb, Mn, Zn and Fe) having low contamination values.

Table 4: Heavy metals contamination factor of agricultural soils sample

Sample site	Contamination Factor (CF)					
	Pb	Cr	Cd	Mn	Zn	Fe
Maska 1	0.3865	1.6304	3.3333	0.7692	0.2389	0.0081
Maska 2	0.4831	1.0869	6.6666	0.5128	0.1493	0.0120
Maska 3	0.0174	0.0869	20.0000	0.0256	0.2987	0.0080
Maigamji 1	0.0961	1.6304	13.3333	0.7692	0.2195	0.0107
Maiganji 2	0.2898	0.0111	3.3333	0.5128	0.1792	0.0269
Maiganji 3	0.0966	1.0869	3.3333	0.5128	0.4273	0.0028
Goya 1	0.0977	0.0869	3.3333	0.2564	0.1194	0.0460
Goya 2	0.1923	0.5444	10.0000	0.5128	0.1195	0.0267
Goya 3	0.0966	1.6304	13.3333	0.5897	0.1197	0.0080
Dikke 1	0.2899	2.0000	6.6666	0.5128	0.1792	0.0669
Dikke 2	0.0966	1.0869	3.3333	0.5128	0.2389	0.0080
Dikke 3	0.2898	1.0869	6.6666	0.6410	0.1195	0.0067

4.0 CONCLUSION

Based on the findings, all analyzed soil parameters were found to be low in agricultural soils. Although Cd was slightly higher than the remaining metals. Geo-accumulation index result revealed that the soil is unpolluted and contamination factor shows the relative distributions of the contamination factor among the samples were described as $Cd > Cr > Mn > Zn > Pb > Fe$. For all soil samples the heavy metal Cd has a CF values ranging from 3.3333-20.00, indicating that the agricultural soil samples are very highly contaminated with Cd. Cr contamination values ranges from 0.011-2.000, indicating that the soil samples were moderately contaminated. The remaining heavy metals (Pb, Mn, Zn and Fe) indicated low contamination class. Above all, no elevated level of concentration was found in this study. Results of this study provide farm managers, government and non-governmental agencies with invaluable information for the current qualitative level and status of the studied agricultural soils in Funtua area of Katsina state. It is recommended that continuous monitoring of heavy metals in the area should be taken into consideration. Low amount rate of agrochemicals application was also advised.

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