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Soil Factors Influencing the Availability of Manganese and Physico-Chemical Properties in Soils of Different Land-Use Systems in A Coastal Plain Sands of Umudike

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ABSTRACT

The research was conducted in 2017 at the Michael Okpara University Agriculture, Umudike, Nigeria to investigate soil factors influencing the availability of Mn and physic-chemical properties in soils of different land-use systems. Soil samples were collected from two depths (0-20 and 20-40 cm) from five selected land use types, cassava farm, natural fallow, rice farm, forest and grazing fields. Available Mn in the soils was determined using four extractants; Coca-Cola, EDTA, HCl and NH4OAc. The results showed that, higher mean values of physical and chemical properties were generally recorded in the surface (0-20 cm) compared to the subsurface (20-40 cm) soil layer and were also significantly affected by the land use. The highest and the lowest mean values of available Mn were obtained in flood rice farm and cassava farm, respectively. The availability of Mn varied widely depending on the extraction used which, were in the order of Coca-Cola > EDTA > NH4OAc > HCl extractants. Manganese extracted by all extractants was positively and well correlated with organic matter and pH (only the HCl-Mn was negatively correlated with soil pH), which suggests that these soil properties were responsible for the availability of Mn in the soils.

Keywords: *Extractable-Mn, soil physico-chemical properties, soil depth, land uses*

INTRODUCTION

Soil is vital to agricultural production, and with the rapidly increasing population on land to meet the demand for food and fiber, is becoming enormous. The changes in soil properties depends on land use as well as management practices (Sharma *et al*, 2005). Land use and practices, can greatly influenced soil physiochemical properties which in turn, affects the availability of micronutrients (Cu, Fe, Mn and Zn). Changes in land use usually leads to a change in cultivation management, which can have a marked effect on the soil properties (Hassan *et al.*, 2016). In most cases it is the major factor in determining soil fertility (Fayissa, *et al.*, 2015**)**. It is important to gain sufficient knowledge about the effects of different types of land use on soil properties and on the capacity of the soil to fulfill certain functions. The capacity of soil to function can be reflected by measured soil physical, chemical and biological properties (Kiflu and Beyene, 2013). Soil properties deteriorate with change in land use especially from forest to arable land (Ogeh and Ogwurike, 2006; Oguike and Mbagwu, 2009). The improper cropping system may lead to erosion and leaching of soil nutrients which in turn adversely affect the physico-chemical properties of the soil.

Apart from nitrogen (N), phosphorus (P) and potassium (K), the soils of the study area are becoming deficient in available micronutrients cations such as copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn). Different land use system influence availability of these cations by altering their distribution and chemical forms through the influence of soil pH, texture, organic matter (OM) and cation exchange capacity (CEC) (Dhaliwel *et al.*, 2009). Accordingly, the effects of land use pattern on micronutrients accumulation in soil have been investigated elsewhere with focus on cultivated, forest and grazing land (Yeshaneh, 2015; Ivana *et al.*, 2015).

Soil properties are very important characteristics particularly when they are to be put into agronomic uses. Different land uses often occur on similar soils. Essentially micronutrients have become a focus of public interest since analytical techniques have made it possible to detect even in very small amounts. The purpose of this research was focusing on soil factors influencing the availability of Mn and physico-chemical properties in soils of different land-use systems.

MATERIALS AND METHODS

The Study Area

The study was conducted at Michael Okpara University of Agriculture Umudike, Nigeria which is located between (Latitude 05^{0} 29'N and Longitude 07^{0} 33'E). The altitude of the sample area ranges from 97 to 118 m above sea level with slopes which ranged from level to gentle slope.

The area falls within the tropical rain forest with mean annual rainfall of 2200 mm, distributed over nine to ten months in bimodal rainfall pattern; these are the early rain (April to July) and late rains (September to October) with five months dry season and a short dry period in August popularly called August break. The relative humidity varies from 74% to 87% while, monthly minimum air temperature ranged from 20 ^{o}C to 24 ^{o}C and monthly maximum air temperature which ranged from 28^{o}C to 35 ^{o}C (NRCRI, 2016).

The area is also subjected to severe water erosion during rainy seasons, which causes nutrient losses. In the university are does not exist a high possibility of increasing the agricultural production due to the increased pressure on other land use systems (construction of classroom blocks, offices, students' hostels, recreational parks, etc).

Site Selection and Sample Collection

At the beginning of the study (April, 2017), a general visual field survey was carried out to have a general view of the variations in the sstudy area. Representative soil sampling sites were selected from five land use types which were categorized into: cultivated (cassava farm), natural fallow (legume fallow), flood plain (rice farm), forested (reserved) and pasture (grazing) lands, respectively. A random soil samples from 0-20 cm and 20-40 cm depths were collected using a soil auger to make composite samples and replicated three times (different fields) for each land use type, within the study area. A total of thirty (30) soil samples (5 land use x 2 depths x 3 replicates) were collected for the study. The study sites were geo-referenced with the aid of global positioning system (GPS) and their coordinates well documented.

Sample Preparation and Analysis

The soil samples collected were air-dried and passed through a 2 mm sieve for the analysis of selected soil physical and chemical properties and for content of available Mn. Separate soil core samples from the 0-20 and 20-40 cm depths were taken with a sharp-edged steel cylinder forced manually into the soil for bulk density determination.

Analysis of Soil Physical Properties

Soil texture was determined using hydrometer method (Gee and Or, 2002). Soil bulk density was determined by the pycnometer method. Total porosity was estimated from the values of bulk density and particle density, with the latter assumed to have the generally used average value of 2.65 g cm^{-3} as:

Total Porosity (%) =

$$1 - \frac{\text{Bulk density (Bd)}}{\text{Particle density (Pd)}} \text{ x } 100$$

Soil moisture content was determined by oven dry method using 10 g of fresh soil. Soil samples were kept in oven for 24 hours at 60 ^{o}C.

Analysis of Some Soil Chemical Properties

Soil pH was determined in a 1:2.5, using the soil: water and CaCl$_2$ suspension method (Thomas, 1996). Soil organic carbon was measured using the wet oxidation colorimetric method (Nelson and Sommers, 1996). Organic carbon was converted to OM by multiplication using a factor of 1.724 (Van Bemmelen factor). Total N was determined by the Kjeldahl digestion and distillation procedure described by Bremner **(**1996). Available P was determined using Bray and Kutz II solution (Olsen and Summer 1982). Exchangeable bases (Ca, Mg, K, and Na) were extracted with neutral NH4OAc. Ca and Mg was determined in the extract by EDTA titration, while K and Na were determined using the flame photometer. Exchangeable acidity was determined by leaching with KCl and the leacheate titrated with 0.05N NaOH. The effective CEC (ECEC) of the soil was determined by summing the total exchangeable bases (TEB) and the exchangeable acidity (EA=H + Al) using the standard method proposed by Sumner and Miller (1996). Percentage base saturation was determined by calculating the sum of all exchangeable bases multiplied by 100% and divided by the ECEC as follows:

$$\text{Base Saturation} = \frac{ExchageableCation}{ECEC} \times \frac{100}{1}$$

Determination of Available Manganese

The available Mn was determined using Coca-Cola solution, ammonium acetate (1 N NH_4OAc), ethylenediaminetetra acetic acid (0.005N EDTA) and dilute hydrochloric acid (0.1 M HCl) methods, as described by Eteng *et al*. (2014) and Eteng and Asawalam (2016). The Mn concentration in the supernatant was determined using an atomic absorption spectrophotometer (AAS) employing atomization in an air/ acetylene flame using PG-Model AA-500.

Statistical Analysis

The data generated on the soil properties and forms of soil Mn by different extractants were subjected to analysis of variance (ANOVA) procedure using Genstat 12th edition. Significant means were separated using Fisher's least significant different test, at a probability (P) level of 5%. Pearson correlation analysis was performed to determine the relationship between soil properties and forms of soil Mn using SPSS version 20. The significance of the relationship was tested at $P<0.05$.

RESULTS AND DISCUSSION

Soil Particle Size Distribution as Influenced by Land use and Soil Depth

The contents of sand, silt and clay fractions as influenced by land use type, soil depth and the interaction effects are presented in Table 1. The highest (80.7 %) and the lowest (61.9 %) average sand fraction were observed at the surface (0-20 cm) layer of the cultivated land and the subsurface layer of the flood plain lands, respectively (Table 1).

Similarly, the highest (28.9 %) and the lowest (10.4 %) average clay fraction were determined on the subsurface (20-40 cm) and surface layers, respectively of the forested and the flood plain lands, respectively. The texture of the soils ranged from sandy loamy (SL), sandy clay loam (SCL) and Loamy (LS) (Table 1). The results show that the clay fraction increased whilst the sand decreased from the surface to the subsurface horizons in these two types of land use systems. Higher percentage of clay content in subsurface soil (20-40 cm) might be due to the eluviation and illuviation process. Similar trend of gradual increase in clay content with depth was reported by Agoumé and Birang (2009) and (Oguike and Mbagwu, 2009).

Bulk Density, Total Porosity and Soil Moisture as Influenced by Land use and Soil Depth

With the exception of bulk density and moisture, content of total porosity was significantly ($P < 0.05$) affected by land use and soil depth (Table 1). Total porosity in soils was highest at the surface (0-20 cm) layer (49.78 %) opf the flood plain and the cultivated and lowest (21.92 %) at the subsurface (20-40 cm) layer of the forest soil (Table 1). In general, total porosity decreased with increasing soil depth. The results obtained from this study are in agreement with the findings reported by other researchers (Oguike and Mbagwu, 2009).

Table1. *Effects of land uses and soil depth on the distribution physical property of the study soils.*

Land uses	Depth (cm)	Particles size			Textural class	Bulk density (mgm^{-3})	Total porosity (%)	Moisture content (gkg^{-1})
		Sand	Silt	Clay				
Cassava farm	0-20	65.8	20.6	13.6	**SL**	1.47	33.22	108.12
	20-40	68.4	16.1	15.5	**SL**	1.86	27.35	123.12
Legume Fallow	0-20	66.3	13.8	19.9	**SL**	1.22	37.84	130.25
	20-40	70.1	9.2	20.7	**SCL**	1.93	24.63	130.31
Swamp rice farm	0-20	80.7	8.9	10.4	**LS**	1.16	49.78	169.47
	20-40	77.4	6.5	16.1	**SL**	1.54	34.84	116.14
Forested land	0-20	61.9	13.3	24.8	**SCL**	1.58	38.33	146.25
	20-40	60.2	10.9	28.9	**SCL**	1.41	35.61	139.45
Grazing land	0-20	70.5	14.8	14.7	**SL**	1.97	25.43	116.05
	20-40	68.8	7.4	23.8	**SCL**	1.42	21.92	132.24
Mean		68.51	12.15	19.34	**SL**	1.57	32.90	131.14
LSD (0.05)		2.78	6.15	6.74		0.57	7.02	35.18
CV (%)		1.5	18.10	11.00		20.52	12.21	15.33
Probability		0.006	0.127	0.023		0.37	0.033	0.630

Soil Chemical Properties as Influenced by Land use and Soil Depth

The results of the chemical properties of the soils were significantly ($P < 0.05$) affected by land use, soil depth and the interaction effects (Table 2).

Soil Reaction

Changes in land use resulted in reduction of soil pH from pH-H_2O (6.40 to 4.20) and pH-KCl (5.50 to 3.70) at the surface soils (0-20 cm) and sub-surface soils (20-40 cm) layers of the natural and fallow land, respectively.

Total Nitrogen

The content of total N was highest (0.22 g/kg) and lowest (0.07 g/kg) under the surface (0-20 cm) and lower (20-40 cm) layers of the cassava soil and the grazing pasture, respectively (Table 2). In general, total N values decreased with increasing soil depth and these were highly significant ($P < 0.05$). The result agrees with the findings of Yeshaneh (2015) and Hassan *et al* (2016).

Available Phosphorus

The available P content of the soils with regards to land use types and soil depth had the highest (29.40 mg/kg) and the lowest (19.00 mg/kg) values at the surface (0-20 cm) layer of the pasture and at the sub-soil (20-40 cm) layer Swamp rice (Table 2). In general, available P contents decreased with increasing soil depth and were highly significant ($P < 0.05$). Similar results were reported by Senjobi and Ogunkunle (2011) and Wasihun (2015).

Exchangeable K

The content of exchangeable K with regards to land use type and soil depth, was highest (0.55 cmol/kg) and lowest (0.18 cmol/kg) at the surface (0-20 cm) layer of the pasture and at the sub-surface (20-40 cm) depths of the cassava (Table 2). In general, values of the exchangeable K decreased with increasing soil depth and were highly significant ($P < 0.05$).

Soil Organic Matter

The highest (5.42 g/kg) and the lowest (1.46 g/kg) values of OM contents were recorded at the surface (0-20 cm) layer of the pasture and at the subsurface soil of the cassava soil, respectively (Table 2). This result is in par with previous studies by Yeshaneh (2015) and Hassan *et al* (2016). Generally, OM decreased significant ($P < 0.05$) with increasing depth. This implies that the surface soil layer is the most biologically active of the soil profile. Meanwhile, the low OM content (1.98 g/kg) in the upper layer (0-20 cm) of cultivated soil might be due to the highest temperature and rainfall, which accelerated the rate of decomposition of organic matter (Senjobi and Ogunkunle, 2011).

The Effective Cation Exchange Capacity (ECEC)

There was higher (16.53 cmol/kg) at the surface (0-20 cm) layer of the pasture and lower (4.95 cmol/kg) at 20-40 cm of the cassava soil (Table 2). In general, ECEC values decreased significantly ($P < 0.05$) with increasing soil depth. Similar results were reported by Mustapha *et al.* (2010) and Wasihun (2015) and Hassan *et al.* (2016). These authors reported that any soil < 4 cmol/kg ECEC is less productive. The decrease in the ECEC of this study area with depth could be due to the positive and significant correlation correlation with the OM ($r = 0.74^{**}$) (Table 3).

Percent Base Saturation

Percent base saturation (BS) considering the effects of land use and soil depth was highest (95.13 %) in pasture soil and lowest in the cultivated land (61.73 %) at the surface (0-20 cm) and lower layers respectively (Table 4). In general, BS% was decreased significantly ($P < 0.05$) with soil depth. Similar results were reported by Yeshaneh (2015) and Hassan *et al* (2016).

Correlation Matrix among the Distribution of Physical and Chemical Properties of Soils under the Land use Types and Soil Depth

The result of correlation matrix among the distribution of physical and chemical properties of soils under various land uses and soil depths are shown in Table 3. In this study, clay fraction correlated positively with OM (0.76**), total N (0.61*) and negatively correlated with exchangeable K (-0.58*). Hence, increasing clay content in soils provides more sites for adsorption of metals thus reducing bioavailability of K. Soil pH also correlated positively with total N (0.44*) and negatively correlated with ECEC (-0.44*). Soil organic matter also correlated positively with total N (0.92**), exchangeable K (0.97**), ECEC (0.638*) and base saturation (0.73**). Total N also correlated positively with exchangeable K (0.96**). These results are similar with those reported by Yeshaneh (2015) and Hassan *et al.* (2016).

Table2. *Distribution of some chemical properties of the soils as influenced Land use types and soil depths*

Land use types	Soil Depth	pH (H_2O)	pH (KCl)	Basic Nutrient Elements			Org. M	ECEC	BS
				Total N	Exch. K	Av. P			
	Cm			g/kg	cmol/kg	mg/kg	g/kg	cmol/kg	%
Cassava farm	0-20	5.30	4.50	0.10	0.20	27.40	1.98	5.15	76.68
	20-40	4.20	3.90	0.07	0.18	23.20	1.46	4.95	61.73
Natural Fallow	0-20	6.40	5.50	0.18	0.38	26.20	3.29	9.36	90.59
	20-40	5.60	4.80	0.12	0.31	19.50	2.77	8.96	83.92
Swamp rice farm	0-20	4.80	4.40	0.21	0.50	19.80	5.21	13.45	73.45
	20-40	4.40	3.70	0.18	0.44	19.00	4.95	11.25	89.33
Forested land	0-20	5.80	5.00	0.20	0.43	25.50	3.70	14.48	93.37
	20-40	5.10	4.10	0.14	0.34	21.60	2.82	9.44	86.44
Grazing land	0-20	5.50	4.80	0.22	0.55	29.10	5.42	16.53	95.13
	20-40	5.30	4.00	0.19	0.53	20.30	4.54	15.34	93.22
Mean		5.41	4.51	0.16	0.39	23.26	3.61	10.82	84.39
LSD (0.05)		0.37	0.38	0.04	0.06	5.60	0.52	3.69	22.58
CV %		2.4	3.0	8.4	5.8	8.7	15.2	12.3	9.6
Probability		0.012	0.010	0.005	<0.001	0.016	<0.001	0.007	0.022

Table3. *Relationship among the distribution of physical and chemical properties under various land uses and soil depth*

Soil properties	Physical characteristics of soil					Chemical characteristics of soil						
	Sand	Silt	Clay	BD	TP	pH	Org M	Total N	Av P	K	ECEC	BS
Sand	-											
Silt	0.55*	-										
Clay	**-0.88****	**-0.86****	-									
BD	-0.26^{NS}	-0.36^{NS}	0.35^{NS}	-								
TP	-0.06^{NS}	0.67*	-0.35^{NS}	-0.69*	-							
pH-H_2O	0.15^{NS}	0.27^{NS}	-0.25^{NS}	-0.42*	0.45*	-						
Org M	**0.73****	0.69*	**-0.76****	-0.27 NS	0.20^{NS}	0.17^{NS}	-					
TN	0.58*	0.48*	-0.61*	-0.38 NS	0.20^{NS}	0.44*	**0.92****	-				
Av P	0.17^{NS}	-0.13^{NS}	-0.02^{NS}	-0.04 NS	0.28^{NS}	0.35^{NS}	-0.11^{NS}	0.08^{NS}	-			
K	0.62*	0.40*	-0.58*	-0.26 NS	0.12^{NS}	0.24^{NS}	**0.97****	**0.96****	-0.05 NS	-		
ECEC	0.36^{NS}	-0.02^{NS}	-0.19^{NS}	-0.21 NS	-0.19 NS	0.44*	**0.74****	**0.81****	0.22 NS	**0.80****	-	
BS	0.33^{NS}	0.10^{NS}	-0.24^{NS}	-0.01 NS	0.01^{NS}	0.15^{NS}	**0.73****	**0.73****	-0.03 NS	**0.79****	**0.72****	-

*BD= Bulk density, TP = Total porosity, NS = not significant at 5% probability, * = significant at 5% probability, ** = significant at 1% probability*

The Distribution of Available Manganese in Soils as Influenced by Land uses and Soil Depth

Significant variation of available Mn in the soil was observed among the different land use types and soil depth by different extractants (Table 4). Considering the effects of land uses and soil depth on available Mn in soils, content of EDTA-extractable Mn was highest (36.67 mgkg^{-1}) under the surface (0-20 cm) layer of flood plain land and lowest (5.17 mgkg^{-1}) in the subsurface (20-40 cm) layer of the cultivated land. Mn-HCl was highest (34.57 mgkg^{-1}) under the surface (0-20 cm) layer of flood plain and lowest (4.48 mgkg^{-1}) in the sub-surface (20-40 cm) layer of the cultivated land. NH$_4$OAc extractable Mn was highest (18.87 mgkg^{-1}) under the surface (0-20 cm) layer of natural fallow land and lowest (7.67 mgkg^{-1}) in the subsurface (20-40 cm) layer of the pasture land. Similarly, Coca-Cola-extractable Mn was highest (33.34 mgkg^{-1}) under the surface (0-20 cm) layer of natural fallow land and lowest (9.02 mgkg^{-1}) in the subsurface (20-40 cm) layer of the cultivated land. These results are similar to those reported by Yeshaneh (2015), Ivana *et al*. (2015) and Onwudike *et al.* (2016).

The level of extractability was in the order of: Coca-Cola > EDTA > NH$_4$OAc > HCl extractant. This observation is in line with those of Kiflu and Beyene (2013), Eteng *et al.* (2014) and Hassan *et al.* (2016). The main conclusion from Table 5 is that extractable Mn by all extractants were correlated with soil pH and OM content. Nevertheless, these correlations do not always have the same tendency (sometimes are positive, others are negative).

Table4. *Effects of land use on the distribution of total and available Mn in soils*

Land use	**Soil depth (Cm)**	**Available Mn (mgkg^{-1})**				
		Mn-EDTA	**Mn-HCl**	**Mn-NH$_4$OAc**	**Mn-CC**	**Mean**
Cassava farm	0-20	7.96	9.96	9.13	13.24	8.46
	20-40	5.17	4.48	8.73	9.02	
Natural Fallow	0-20	14.76	7.36	18.87	33.34	13.78
	20-40	5.96	6.67	10.87	12.43	
Swamp rice farm	0-20	36.67	17.96	15.59	25.23	19.05
	20-40	16.46	10.34	11.89	18.26	
Forested land	0-20	15.48	8.46	16.22	17.18	12.72
	20-40	12.36	6.16	13.59	12.31	
Grazing land	0-20	9.16	34.57	11.86	18.16	10.92
	20-40	6.16	14.32	7.67	15.45	
Mean		14.01	9.53	12.44	17.46	13.74
LSD (0.05)		7.43	7.52	4.76	6.79	
CV (%)		22.10	27.10	13.4	29.4	
Probability		0.014	0.024	0.028	0.033	

Soil Factors that Influenced the Distribution of Availability of Mn in Soils under Different Agricultural Land-Use System

The results on the determinant factors responsible for the availability of Mn in soils are presented in Table 5. The high positive correlation between OM and available Mn, indicating that, as OM content increase, availability of Mn increase which may be due to the formation of organic matter complexes, and this could be attributed to the chelating property of OM that helps to hold this nutrient in the soil. Similar observation were made by Hassan *et al.*, (2016) who reported a positive significant correlation between Mn and organic carbon and attributed it to the complexing agents generated by organic matter which promote Mn availability in the soil. The significant correlation with OM indicates the role of SOM in reducing the availability of Mn in the soils (Kumar and Babel, 2011; Onwudike *et al.*, 2015).

Similarly, soil pH indicated negative correlation with available Mn, indicating that, increase in pH results in a reduction of soil available Mn. Other studies have indicated that soil pH influences micronutrients availability by favouring conditions which accelerates oxidation, precipitation, and immobilization (Ibrahim *et al.*, 2011; Hassan *et al.*, 2016). In contrast, the positive correlations were found between NH$_4$OAc- and EDTA-extractable Mn with soil pH which however provides favourable conditions for their availability. Similar results were reported by Yi *et al*. (2012); Ivana *et al.* (2015); Yeshaneh (2015).

Table5. _Relationship between the distributions of available forms of Mn and some selected soil properties as influenced by land use and soil depth_

Soil properties	Extractable manganese (Mn) (mg/kg)			
	EDTA	**HCl**	**NH_4OAc**	**Coca-Cola**
Sand	-0.332 ^{NS}	-0.640*	0.253 ^{NS}	-0.705**
Silt	0.486 ^{NS}	0.098 ^{NS}	0.601*	0.304 ^{NS}
Clay	0.578*	0.415^{NS}	0.489 ^{NS}	0.647*
Bulk density	-0.355 ^{NS}	0.232 ^{NS}	-0.505*	-0.431 ^{NS}
Total porosity	-0.676*	-0.393 ^{NS}	0.594*	0.370 ^{NS}
Moisture content	0.544*	-0.255 ^{NS}	0.032 ^{NS}	0.423 ^{NS}
pH	0.732**	-0.842**	0.603*	-0.779**
Org M	0.609*	0.739**	0.743**	0.810**
ECEC	0.271 ^{NS}	0.598*	-0.673**	0.827**

NS = not significant at 5% probability, * = significant at 5% probability, ** = significant at 1% probability.

Relationship among the Available Forms of Mn that Influences their Availability in Soil Under Land Uses and Soil Depth

In Table 6 the correlations among all Mn-extractants are presented. EDTA-extractable Mn was positively and significantly correlated with Mn-NH_4OAc (0.734**) and Mn-Coca-Cola (0.569*) but negatively and significant correlated with Mn-HCl (-0.631**). On the other hand, HCl extraction correlated positive and significantly with Mn-Coca-Cola (0.790**). These results are in line with those reported by Yeshaneh, (2015) and Hassan *et al.* (2016).

Table6. _Relationship among the distribution of available forms of Mn under various land uses and soil depth_

	Extactable Manganese (Mn) (mg/kg)			
	EDTA	**HCl**	**NH_4OAc**	**Coca-Cola**
Mn-EDTA	-			
Mn –HCl	-0.631**	-		
Mn - NH_4OAc	0.734**	-0.219 ^{NS}	-	
Mn -Coca-Cola	0.569*	0.790 **	0.215 ^{NS}	-

NS = not significant at 5% probability, * = significant at 5% probability, ** = significant at 1% probability

CONCLUSIONS

The study was conducted in a coastal plain sand derived soil of Umudike, Nigeria to investigate soil factors influencing the availability of extractable Mn and physico-chemical properties in soils under different land use systems. The study demonstrated that soil physical and chemical properties were significantly ($P < 0.05$) influenced by land use and soil depth respectively. There were notable variation in soil properties among the land use types and higher contents of the soil properties were in the surface (0-20 cm) than the sub-surface (20-40 cm) layers of soil. Similarly, the distribution of available forms of Mn extracted by EDTA, HCl, NH_4OAc and Coca-Cola were significantly ($P < 0.05$) different under the different land uses and decreased with soil depth. The levels of availability was in the order of Coca-Cola > EDTA > NH_4OAc > HCl. There were significant correlations between the available Mn with soil OM and pH which suggests that these soil properties were responsible for the availability of Mn. In conclusion, available Mn varied widely depending on the extraction method used and the variability observed in the physical and chemical properties of the soils used.

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