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The impact of land use types and acidity indices on soil humic fractions quantities at Umudike, tropical rainforest, Nigeria

*** Onwuka, M. I.[1], Okonta, U [2] and Asobia, P. C.[1]**

[1] *Department of Soil Science and Meteorology, College of Crop and Soil Sciences, Michael Okpara University of Agriculture Umudike, PMB 7627 Umuahia, Abia State, Nigeria*

[2] *Department of Crop Production Technology, Federal College of Agriculture, Ishiagu PMB 7008 Ivo, Ebonyi State, Nigeria.*

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Corresponding Author's E-mail Address:

onwuka.ifeoma@mouau.edu.ng
phone :08124880548

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ABSTRACT

Natural humic fractions deposited in the soil are most times sources of industrial humic substances use for crop production. However, the quantities of the humic substances, which are components of soil organic matter, are affected by lots of factors and processes, including land- use. The effects of different land- use and soil acidi0ty indices on the quantity of soil humic fractions at Umudike, Abia State were studied. To assess these effects, soils samples were collected from a depth of 0-10cm from primary forest land, mixed cropping farm, grassland, pig waste dumpsite cow dung dumpsite, poultry droppings dumpsite and goat dung dumpsite within Umudike area of Abia State, Nigeria. Humic acid, fulvic acid, humin, particle size distribution, pH, exchangeable acidity and organic matter were determined using standard laboratory procedures. Also, relationships between the selected soil acidity indices and humic fractions were estimated. The result showed that goat dung dumpsite had significantly ($P<0.05$) highest mean values of 0.15% and 0.24% for humic acid and humin, respectively. Pig waste and poultry droppings dumpsites had pH values of 6.3 and 6.2, respectively. Soil exchangeable acidity correlated positively ($P<0.05$) with fulvic acid having a coefficient of determination (R) value of 0.0770. The results obtained showed that goat dung dumpsite might serve as a potential natural mining site for artificial humic acid and humin; also acidity indices affect humic fractions in the soil

1.0 Introduction

Land- use system influences soil organic matter (SOM) by determining the type of litter deposited on the soil, the quantity and the rate of turnover (Sainepo *et al.,* 2018). Wolf *et al.* (2005), reported that humic and non- humic substances are the main component of concern during the processes of SOM degradation. Of these components, humic substances which are composed of humic acid, fulvic acid and humin are the major components of the natural soil organic matter and are macromolecules in nature (Sahin *et al.,* 2016). The humic substances are the leading indices of soil fertility (Ufimtseva and Kalganov, 2011). Humic acid, fulvic acid, and humin, which are either soluble in alkaline, acidity or both respectively (Rupiasih and Vidyasagar, 2005), can persist in the soil for longer periods. They represent the most stable proportion of organic carbon that is very important in soil erosion control (Piccolo, 1996).

Humic substances play vital roles in the biogeochemical cycling of nutrients, pollutant behaviour, fate and mobility, increase the soil cation exchange capacity and ensure plant nutrients availability (Weber 2020). It takes an extended time for humic fractions to develop in the soil. This, in most cases, delay the plants and soil from gaining from its numerous benefits. However, through the mining of humic substances from the natural deposits in soil and water, artificial humic substances have been developed. The artificially mined humic substances are applied to soil as fertility booster or plants as a plant growth regulator (Yakimenko and Terekhova 2011). When applied to the plants, they stimulate nutrient uptake, root growth, increase plant resistance to stress, increase elongation of shoots and leaves, control nutrient transportation through plasma membranes and reduce the population of some pathogens (Yakimenko and Terekhova 2011; Halpern *et al.,* 2015; Berbara and Garcia 2014; Muscolo *et al.,* 2007; Yigit and Dikilitas 2008).

Lands are used for different purposes, and all these affect the soil properties, including soil acidity and organic matter composition (Bizuhoraho *et al.,* 2018). Soil organic matter composition and soil reaction (pH) are some of the critical indicators of soil health (Kelly *et al*., 2009; Cardoso *et al.,* 2013). Any change in them will affect soil fertility and productivity immensely (Feller and Beare, 1997; Zech *et al*., 1997). Tellen and Yerima (2018) reported that different land –use affect soil reaction (pH), either by increasing or reducing the acidity/ alkalinity of the soil. Soil acidity affects several soil's physical, chemical, biological properties and processes. It also exerts its influence tremendously on soil biogeochemical processes, especially in the natural environment (Trevisan, 2019). Any change in indices of soil acidity namely pH, exchangeable acidity, exchangeable aluminium, percentage calcium saturation, percentage aluminium saturation, calcium aluminium ration due to soil management practices affects soil properties (Onwuka *et al.,* 2011). Variations in soil organic carbon and soil acidity of soils under different agricultural-land use system have been observed (Tavares, *et al*., 2014; Onwuka and Adesemuyi, 2019).

This investigation hypothesizes that land-use types will affect the quantity of humic substances differently. The aims of this study, therefore, were to determine the effect of land-use types and soil acidity indices on the soil humic fractions; ascertain the land-use type that can be a possible mining area for industrial humic substances and to establish the relationship that exists among soil organic matter, humic fractions and acidity indices in the study area.

2. Materials and Method

2.1 Site Description

The experiment was conducted at the Department of Soil Science and Meteorology Laboratory, Michael Okpara University of Agriculture Umudike (Latitude 05°29`N and longitude 07°33`E). Umudike is located within the tropical rainforest zone having an elevation of 122m above sea level. The mean annual rainfall is 2200mm and distributed over nine to ten months. The relative humidity varies between 51% and 87%. While monthly minimum air temperature range between 20°C to 24°C, the monthly maximum temperature ranged between 28°C to 35°C (NRCRI Meteorological station, 2014).

2.2 Experimental procedure and design

Seven land use types located within the Michael Okpara University of Agriculture Umudike were identified and used for the study. The land use types were: primary forest land, mixed cropping land, grassland, pig dung dumpsite, cow dung dumpsite, poultry droppings dumpsite and goat dung dumpsite. Areas of 10 m by 10 m were mapped out within each identified land-use type for soil sampling. The GPS locations and histories of the land use types are outlined in Table 1.

A random soil sample was collected from a depth of 0-10cm from five spots within each land-use types, respectively. The composite soil samples were then air-dried at room temperature and passed through a 2mm sieve mesh, and three subsamples from each composite of land-use types were used for the laboratory analysis.

Table 1: Location and history of the seven land use types used for the study

Name	GPS location	Year of establishment and history
Primary Forest land (PFL)	05° 28' 42.9"N 007° 32' 31.5"E	Primary forest land being in existence for more than 60 years.
Mixed Cropping Land (MCL)	05° 28' 54.0" N 007° 32' 21.6"E	This has been under continuous cultivation for the past 40 years.
Grass Land (GL)	05° 28' 45.2" N 007° 32' 34.2"E	Football field and other sporting events used since 2001 (19 years).
Pig Waste Dumpsite (PWD)	05° 28' 42.4" N 007° 32' 22.2"E	Established 48 years ago by the then School of Agriculture.
Cow dung dumpsite (CDD)	05° 28' 42.5" N 007° 32' 23.1"E	Established 48 years ago by the then School of Agriculture.
Poultry Droppings Dumpsite (PDD)	05° 28' 42.5" N 007° 32' 23.4"E	Established in 1994 (26 years) by Michael Okpara University of Agriculture Umudike.
Goat Dung Dumpsite (GDD)	05° 28' 42.6" N 007° 32' 23.2"E	Established 48 years ago by the then School of Agriculture for goat dung disposal.

2.3 Laboratory analysis

Soil particle sizes distribution was determined by the hydrometer method of Bouyoucos, (1951) while pH was determined at 1:2.5 soil to water ratio using the glass electrode method (Mclean 1982). The Walkey–Black wet oxidation procedure modified by Nelson and Sommers, (1982) was used to determine soil organic carbon (SOC), the values of SOC were multiplied by 1.72 (*Van Bemmelen Factor)* to get soil organic matter. Exchangeable acidity was determined by the titration method (Thomas 1982). The humic fractions were extracted by the methods described by Mukherjee and Ghosh (1984), Shamsuddin *et al*., (2009) and Jayaganesh and Senthurpandian (2010). Five grams of the air-dried soil samples from the various land-use types were washed with 1 N HCl solution and placed in 250 ml polyethene centrifuge bottles. The soils in the bottles were treated with 50 ml of 0.1 M NaOH solution (alkali). All the polyethene centrifuge bottles were shaken for 24 hours using reciprocal mechanical shaker equilibrated at room temperature (25°C). After the shaking period, the samples were extracted and centrifuged at 15 mins using the Clay Adams (Model: Compact 11 -6 Place) centrifuge. The dark-coloured supernatant of the centrifuged samples was decanted and then acidified with 6 M HCl to adjust the pH to between 1 and 2. The humic acid was allowed to stand for some time at the room temperature. The supernatant that is the fulvic acid was removed from the humic acid extract. The humic acid was centrifuged again for 10 minutes after being washed in a distilled water, and then oven-dried to a constant weight at 40°C. The weight of the oven-dried humic acid was expressed as the percentage of the weight of humic acid in the soils sampled from the various land-use types. The humin was determined by weighing 0.2g of the soil sample into a plastic container. Ten (10) mls of 0.1N NaOH was added and shaken for about 15minutes. The content was transferred into a test tube, centrifuged for about 5minutes and decanted into another test tube. The content was later acidified with Conc H_2SO_4. The test tube was placed in a hot water bath for thirty minutes and allowed to stand for 24hrs, after which the mixture was decanted, and oven-dried.

2.5 Statistical Analysis

The effect of the land use types on humic fractions was compared with one-way analysis of variance (ANOVA). The means of the data were separated using LSD at $p \leq 0.05$. The relationship between soil organic matter, humic fractions and soil acidity indices were estimated using the Pearson correlation in Genstat (19th edition).

3. Results and Discussion

3.1: Effect of land-use types on the particle size distribution

The particle size distribution of textural soil fractions of sand, silt, and clay significantly ($P<0.05$) varied with land use types (Table 2). Sand fraction ranged between 633±0.57 to 763±1.73 g kg^{-1} with PFL and GL having the lowest and highest values for the sand fraction, respectively. Grassland had the lowest silt fraction value of 134±0.57, whereas CDD had the highest significant value of 315±0.87. Clay fractions had values that ranged from 74±0.29 in MCL to 340±0.56 in PFL. The textual classes for the soils of the land-use types were sandy clay, sandy loam and loamy sand. It was noticed that the clay content of PFL was the highest when compared to the land –use types. It could be that there were much lighter soil organic matter fractions in the PFL floor, and these sometimes affect the clay fraction. Shein *et al.,* (2006), reported that the presence of solid-phase organic matter in soil affects particle size distribution data, especially that of the clay fraction. They said that the low densities and fine to medium sizes of the organic matter are sometimes confused with clay fraction; hence the data will be affected. This may be one of the reasons for the high clay fraction recorded in the present work. However, some researchers had reported lower clay content in PFL and higher clay content in MCL due to continuous ploughing of the soil that encourages weathering processes (Yimer *et al.,* 2008).

3.2: Effect of land-use types on some acidity indices

The PIWD had significantly ($p<0.05$) highest pH in water with a value of 6.57 ±0.09; this was followed by PDD (Table 3). The lowest pH value was gotten from land use GL. Apart from PIWD and PDD; all the others had pH values below 5.5. Exchangeable acidity ranged from 3.35±0.08 coml kg^{-1} to 1.62 ±0.09 coml kg^{-1} with the lowest significant ($p<0.05$) value recorded in the PDD. The exchangeable aluminium ranged between 0.85 ±0.01 coml kg^{-1} and 0.19 ±0.01 coml kg^{-1}; with PDD having the lowest significantly ($p<0.05$). The reason for the higher pH value gotten from animal dung dumpsite could be due to the basic cation such as calcium and magnesium, which are contained in their feeds (Gupta *et al.,* 2016). Basic cations displace hydrogen ion from the soil colloid and increase the soil pH, which is an indication of increase alkalinity of the soil (Ano and Ubochi, 2007) and reduces soil acidity. The lower pH and high exchangeable acidity obtained from grassland may be associated with the continuous acidification process of grasslands in humid climates, usually caused by leaching (Čop, 2014); with over 70% of its particle size characterized as sand (Table 2), it is expected that GL will be more porous and prone to leaching.

Table 2: Effect of land use types on soil particle size distribution

Land use type	Sand (Mean ±SEM) (g kg^{-1})	Silt (Mean ±SEM) (g kg^{-1})	Clay (Mean ±SEM) (g kg^{-1})	Textural Class
PFL	525±0.11	135±0.23	340±0.56	Sandy Clay
MCL	736±0.57	190±0.86	74±0.29	Sandy Loam
GL	763±1.73	134±0.57	103±1.15	Sandy Loam
PIWD	670± 1.15	140±0.58	190±0.57	Sandy Loam
CDD	500±1.15	315±0.87	185±0.28	Sandy Loam
PDD	746±0.66	137±0.55	117±0.57	Sandy Loam
GDD	745±2.02	140±0.57	115±2.60	Loamy Sand
Mean	669.28	170.14	160.57	
Lsd (P < 0.05)	3.43	3.11	4.33	

GDD= Goat dung dumpsite; PIDD=Pig waste dumpsite; CDD= Cow dung dumpsite, Mixed cropping land; GL= Grassland; PDD= Poultry dropping dumpsite; PF = Primary forest

Table 3: Effect of land use types on some soil acidity indices

Land use type	**pH(water)**	**Exchangeable acidity (coml kg^{-1})**	**Exchangeable Aluminum (coml kg^{-1})**
PFL	5.27±0.04	2.83±0.10	0.23±0.02
MCL	5.07±0.08	3.35±0.08	0.78±0.02
GL	4.50±0.06	3.68±0.10	0.85±0.01
PIWD	6.57±0.09	1.84±0.07	0.34±0.01
CDD	5.00±0.06	2.63±0.10	0.44±0.02
PDD	6.20±0.05	1.62±0.09	0.19±0.01
GDD	5.40±0.06	2.15±0.09	0.28±0.01
Mean	5.39	2.58	0.44
Lsd (P<0.05)	0.22	0.27	0.04

3.3: Effect of land-use types on humic fractions

Goat dung dumpsite had significantly (P<0.05) increased humic acid (Figure 1). The least values were obtained from GL and PFL. Grassland gave the highest fulvic acid value with a value of 0.11%; this was followed by GDD. The highest humin value was obtained from GDD. The percentage increase of GDD over the other land use types were 50%, 54.17%, 50%, 29.17%, 37.5% and 58.37% respectively for PIWD, CDD, MCL, GL, PDD and PF. The high amount of recalcitrant fractions of humus (humic acid and humin), in GDD is an indication of a high rate of decomposition (Guimaraes *et al.,* 2013). Irshad *et al.,* (2013), also reported a faster rate of decrease in total carbon (which suggests a higher decomposition rate) of goat dung when composted compared to other animal manures. This could be due to the selective browsing nature of goats, choosing to eat the most nutritious and digestible foliage and parts of foliage available (Zhang *et al.,* 2014, Daovy *et al.,* 2008; Fajemisin *et al.*, 1996). The manure in PDD is usually mixed with the litter (wood shaving) thus increasing the C: N ratio of the mixture; likewise the principal constituent of the pig feed is palm kernel cake whose C: N ratio is also high (Kolade *et al.,* 2006), that may also be the reason for the low humic fraction in PIWD because high C: N slows down decomposition. Due to frequent mowing, GL tends to be continually receiving fresh litter deposits; this could be the reason for its higher fulvic acid levels. Some authors (Reddy *et al.,* 2012; Stevenson 1994; Schnitzer, 2000) have also reported high fulvic acid levels from vegetation constantly receiving fresh litter deposits

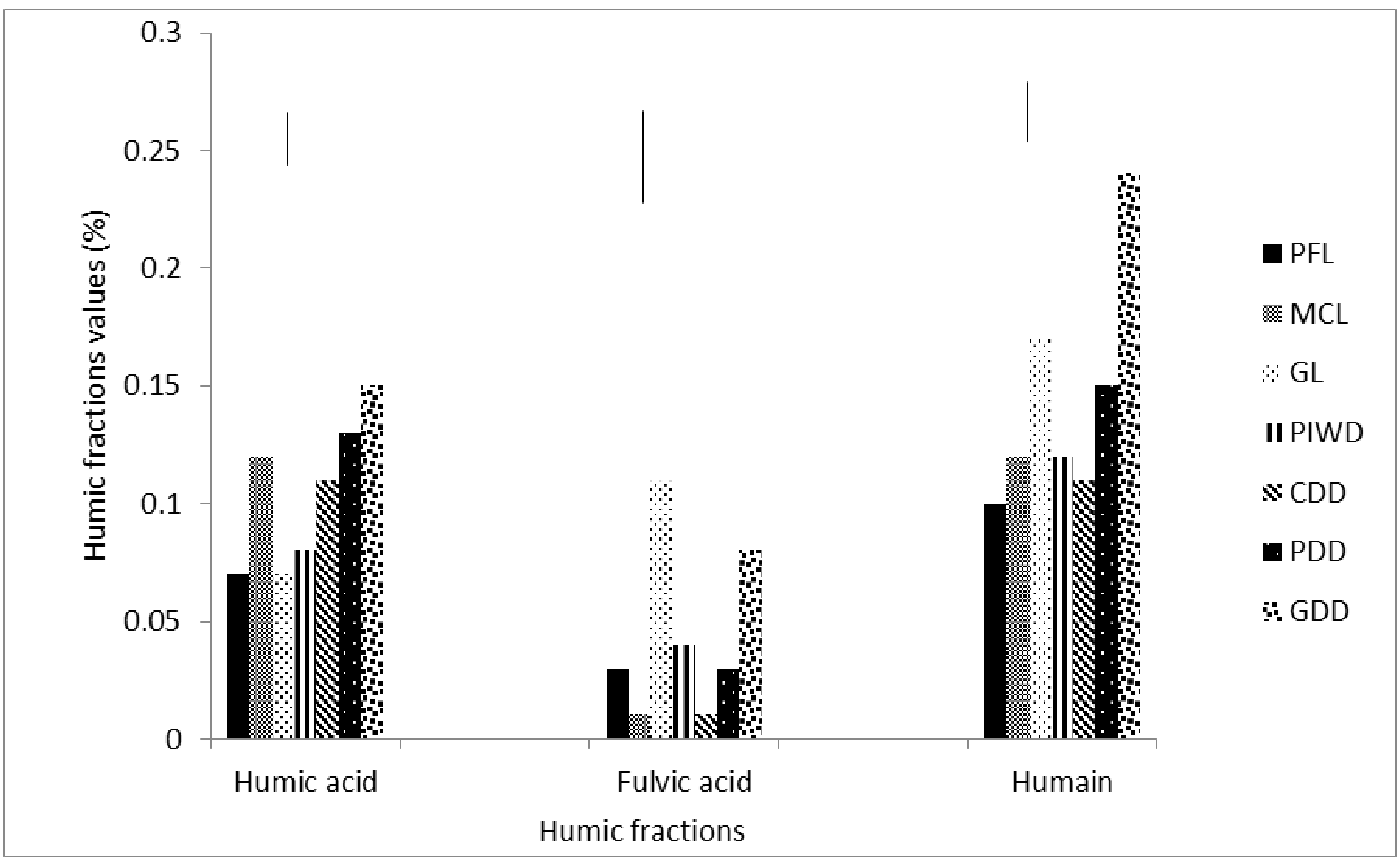

Figure 1: Effect of land use types on humic fractions. Vertical bars represent lsd at P<0.05

3.4: Effect of land-use types on soil organic matter content

The result of the land- use type's effect on soil organic matter, as presented in Figure 2. The result showed that GDD land-use had significantly ($P<0.05$) highest organic matter content than all the land-use types. There was no statistically significant ($P<0.05$) differences between CDD and PDD as each had values of 4.8 and 4.9, respectively. The least value for the organic matter was recorded in MCL land-use. The low MCL recorded in MCL may be due to annual ploughing of the soil which hastens the decomposition process of materials on the soil surface.

3.5 Relationship between some soil acidity indices and the humic fractions of the land- use types

A positive and significant ($p \leq 0.01$) relationship existed between soil pH and humic acid (Table 4) with the values of coefficient of determination (R) and correlation coefficient (r) being 0.0216 and 0-19 respectively. Soil pH had a negative and non-significant relationship with fulvic and humin. Soil exchangeable acidity negatively correlated with humic acid and humin, whereas the correlation of exchangeable acidity and humic acid was significant ($p \leq 0.05$), that of exchangeable acidity and humin was not significant. The influence of pH on microbial activity has been reported (Whittinghill and Hobbie, 2012), with neutral pH favouring higher microbial respiration when compared to soils with acidic pH. Rousk, *et al.,* (2010) also reported a positive relationship between pH with bacteria population and diversity, with microbial diversity doubling between pH 4 and 8. Microorganisms play a decisive role in organic matter decomposition (Singh *et al.,* 2016), hence may be one of the reasons why pH correlated positively with humic acid.

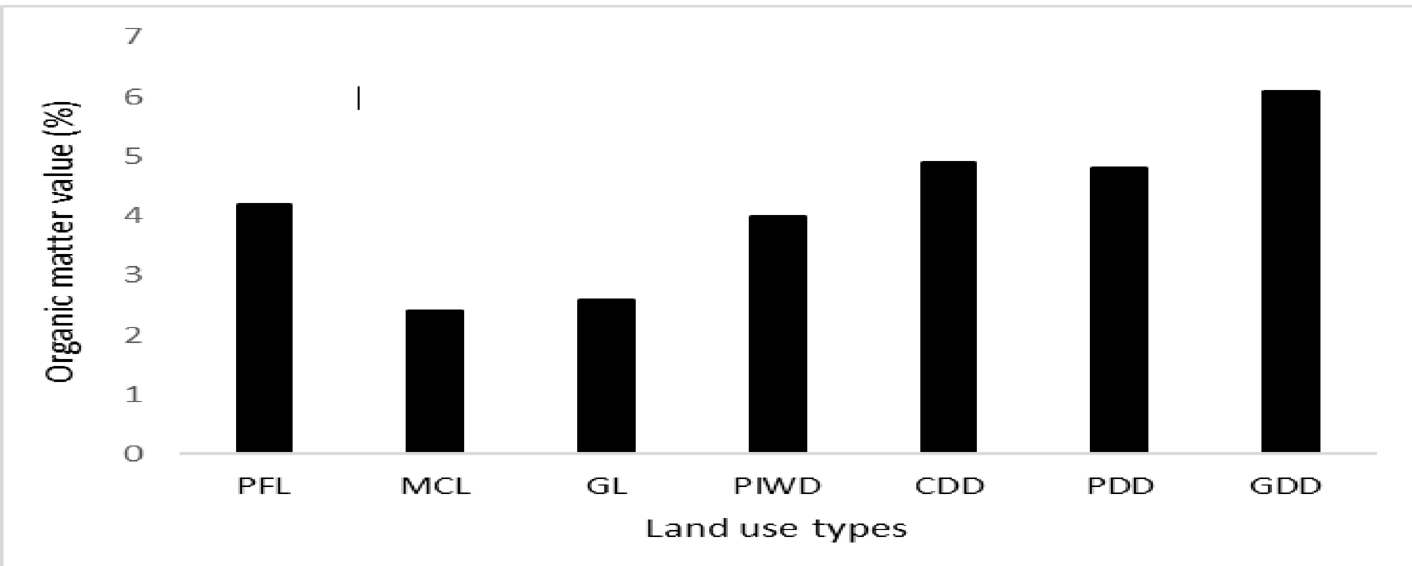

Figure 2: Effect of land use types on soil organic matter. Vertical bar represents lsd at $P<0.05$

Table 4: Relationships between some soil acidity indices and the humic fractions of the land use types studied

Soil properties	Equation	Coefficient of determination (R^2)	Correlation coefficient (r)	Strength of Relationship
Soil pH and humic acid	y=0.0065x + 0.0692	0.0216	0.19*	Positively correlated
Soil pH and fulvic acid	y= -0.0157x + 0.1296	0.0914	-0.30 ^{ns}	Negatively correlated
Soil pH and humin	y= -0.0063x +0.1785	0.0087	-0.07 ^{ns}	Negatively correlated
Soil exchangeable acidity and humic acid	y= -0.0301 x +0.1177	0.0647	-0.47*	Negatively correlated
Soil exchangeable acidity and fulvic acid	y= 0.0389x + 0.0270	0.0770	0.05 ^{ns}	Positively correlated
Soil exchangeable acidity and humin	y= -0.0064x + 0.1471	0.0012	-0.33 ^{ns}	Negatively correlated

*=p ≤ 0.05; ns = non-significant

3.6: Relationship between soil organic matter, pH and exchangeable acidity of the land- use types

There was a linear and positive relationship between soil pH and organic matter (Figure 3). The correlation was significant at P <0.01. This relationship shows that as the pH increases, soil organic matter also increases. The soil exchangeable acidity had an inverse linear relationship with soil organic matter (Figure 4); the relationship was non-significant. This implies that an increase in exchangeable acidity results in a decrease in soil organic matter content of the land use.

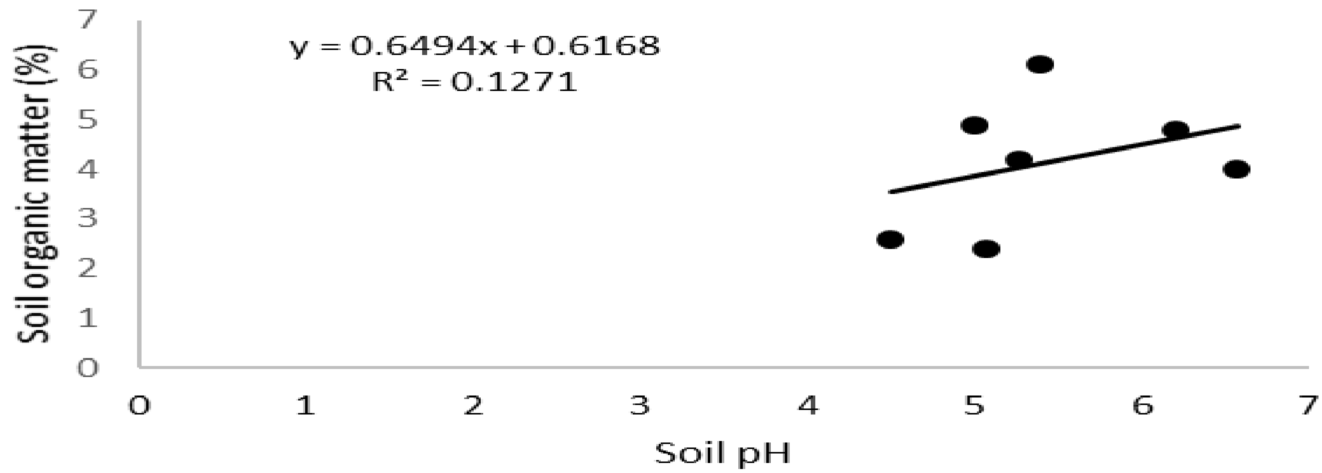

Figure 3: Relationship between soil pH and organic matter in land use types

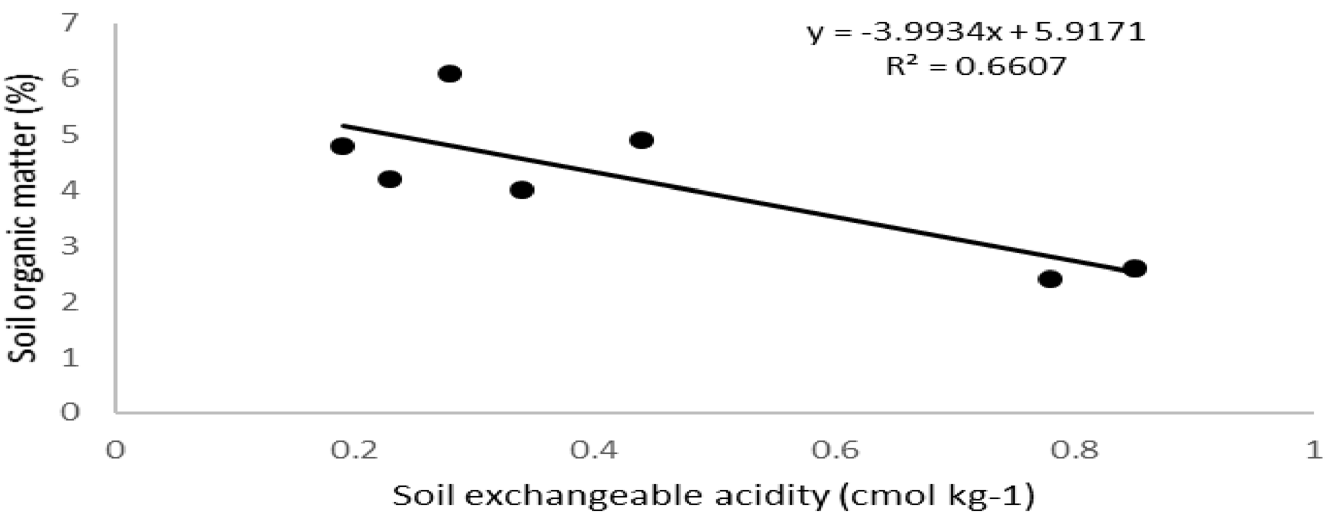

Figure 4: Relationship between soil exchangeable acidity and organic matter in land use types

4.0 Conclusion

There is variation in the influence of different land-use on soil particle size distribution, pH, exchangeable acidity, organic matter and humic fractions. The dung dumpsites particularly PIDD, PDD and GDD increased soil pH, humic acid, organic matter and reduced soil acidity. The result of the study showed that artificial humic fraction could be mined effectively from the animal dung dumpsites. Also increasing the soil pH will promote the production of the humic fraction in the soil. Where artificial mining is not possible, the conversion of the dung dumpsites into arable farms and including the dumpsites into crop rotation practice could be a way of tapping the potentials of the soil properties for crop production.

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