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EFFECTS OF POULTRY LITTER ON SOIL PHYSICO-CHEMICAL PROPERTIES FOR CROP PRODUCTION IN KAURU LOCAL GOVERNMENT AREA, KADUNA STATE, NIGERIA

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ABSTRACT

Poultry litter is an important source of soil nutrients that supports beneficial soil bacteria by serving as a substrate, however, its excessive have adverse effects that lead to soil pollution, contamination and acidification of soil and groundwater. This study analyzed the effects of poultry litter on soil physico-chemical properties for crop production in Kauru Local Government Area, Kaduna State, Nigeria. Data on soil properties at the control and poultry littered sites were collected by sampling four farmlands in Barwa, Ungwan Noma, Kurmin-Shado and Dan-Daura and analyzed in the laboratory. Results were subjected to ANOVA and Correlation analyses tools. The findings revealed significant changes in soil physico-chemical properties due to excessive poultry litter application. Compared to the control site, treated soil showed increased pH (6.26 to 6.89), decreased organic carbon (4.29 to 3.63), increased organic matter (5.92 to 6.99), increased total nitrogen (0.49 to 0.58), altered particle size distribution (clay, silt, sand), reduced aggregate, stability (0.818 to 0.715) and increased CO_2 (64.8 to 65.88%). Also, Correlation analysis revealed a significant relationship between poultry litter application and soil physico-chemical properties (Sig. value >0.05), indicating that poultry manure significantly alters soil parameters. The study concludes that while some of the soil properties identified were within safe limits, application of poultry manure altered other properties of the soil. Thus, the study recommends that farmers should use poultry litter in conjunction with other fertilizers and soil amendments to balance nutrient inputs.

Keywords: Physico-chemical, Poultry Litter, Soil, Soil properties

INTRODUCTION

Poultry litter is made up of waste materials from chicken, geese, duck, quail and turkey farming. The litter comprise of bedding, feed, feathers, manure, and mortalities accumulated throughout poultry production period (Rushing et al., 2020). Poultry litter is an important source of soil nutrients. It contains trace (minor) elements of Boron (b), Zinc (Zn), Manganese (Mn) and non-trace (major) elements like Nitrogen (N), Organic Carbon (C), Calcium (Ca), Magnesium (Mg), Potassium (K), Iron (Fe) and Zinc (Zn). All these elements enhance soil productivity and quality by improving aggregate formation and stability. Poultry litter improves water infiltration capacity (Bolan et al., 2010; Egwu et al., 2023). It also enhances soil health vis-à-vis fertility and increase organic matter content (Ashworth et al., 2017). Poultry litter also supports beneficial soil bacteria by serving as a substrate (Yang et al., 2019). However, an excess of these elements from poultry litter can have adverse effects that lead to soil pollution, contamination by acidification of the soil and groundwater from seepage, assimilation by forage which can contaminate the food chain (Tsai and Chang, 2022).

Soil physicochemical properties refer to the physical and chemical characteristics of soil that influence its fertility, productivity, and overall health. They provide insights into the availability and movement of nutrients, water-holding capacity, ability to retain and release plant nutrients, soil structure, and the interaction between soil and other components in the environment (Lamare and Singh 2019). Studies, especially that of Dexter et al., (2010) revealed that continuous application of manure or litter can increase the levels of trace and non-trace elements in the soil. These are the major and essential ingredient of the soil fertility, thus, creating a reservoir of soil nutrients from deposits over several years after application. This is because only a portion of Nitrogen and other nutrients are made available to plants by soil microbes in the year following application. Eghball et al. (2002) stated that 55% of the nitrogen in poultry litter becomes available to plants in the year of application, indicating that 45% of the nitrogen is available in succeeding years. Furthermore, results of studies indicated that there is contamination of perennial forage plants like Bermuda grass with these metals across various regions (Adeli et al., 2006; Brink et al., 2020). Managing poultry litter entails a complex approach that requires overcoming a number of obstacles such as handling of the litter, application on crops, storage and transportation, changes in the type, composition of poultry litter due to seasonality and breeding regime and technological operations such as pre-treatments and post-treatments (Ashworth et al., 2014; Drozdz et al., 2020).

It has been observed that in Kauru LGA, Kaduna State arable farmers apply poultry litter to farmlands to increase yield especially in crops like maize and Guinea corn. It is also clear that poultry litter have both positive and negative impacts on soil physicochemical properties. The negative aspects are the problems this study intends to assess and proffer solutions to in Kauru Local Government Area of Kaduna State; hence, this study is embarked upon to identify the effects of poultry litter on soil physiochemical properties in Kauru LGA, Kaduna State, Nigeria.

MATERIALS AND METHODS

Study Area

Kauru Local Government Area is located between Latitude 9°40'23"N to 10°35'35"N of the Equator and Longitude 7°57'11"E to 8°39'11"E of the Greenwich Meridian. With an area of about 3186Km2, the LGA is bounded in the Northeast by Soba L.G.A, North West by Kubau L.G.A., and in the South-East by Kauru L.G.A. in the South-West by Zangon-Kataf LGA, it is also bounded in the East by Kajuru LGA and in the West by Lere LGA (Figure 1). It is in the South-Eastern part of Kaduna State. Kauru LGA has an average altitude of about 1042 meters above the sea level. It was created out of the former Saminaka LGA (now Lere LGA) by the Babangida Administration in 1989 (Tubayini, 2000).

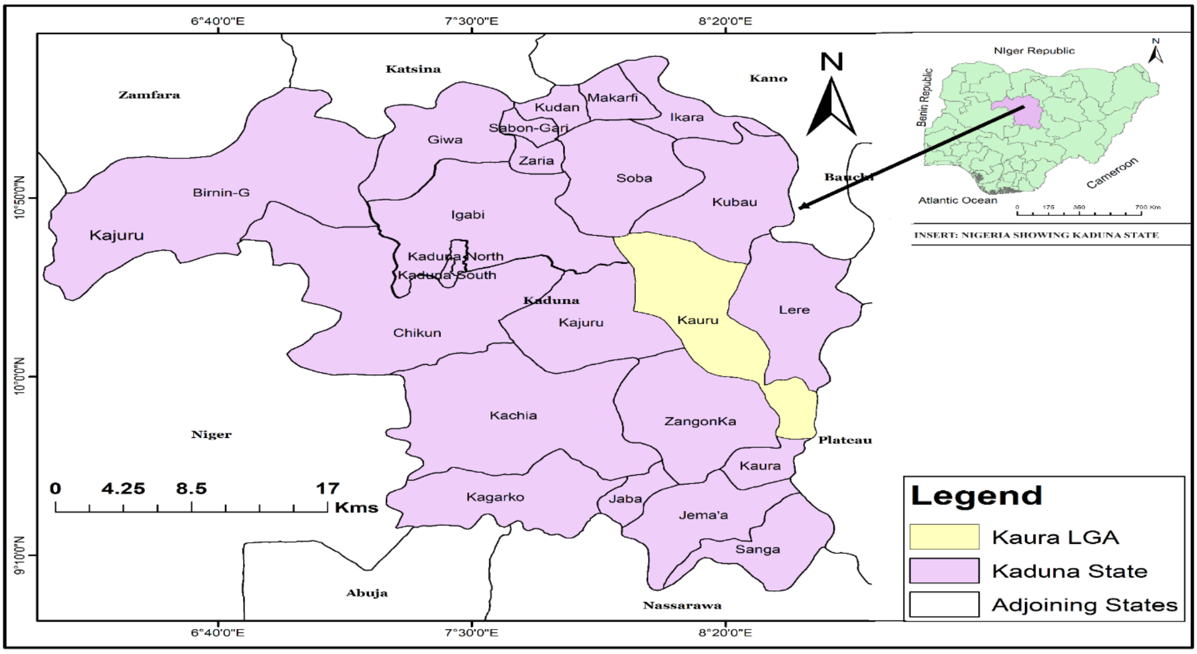

Figure 1: Map of Kaduna State Showing Kauru Local Government Area.
Source: Adapted from the Administrative Map of Kaduna State (2024)

Types and Sources of Data Used

Soil samples were collected from some selected farms using auger for laboratory test. These farms were purposively selected and sampled out of four wards in Kauru LGA due to the high use of poultry litter as manure. Six samples were collected from each ward, (three from the littered sites and another three from the control sites). The wards Barwa, Ungwan-Noma, Kurmin-shado and Dan-Daura. The coordinates of those locations were captured using a handheld GPS receiver.

Table 1: Location of Sampling points

Code	Location	Points	Latitude	Longitude
DAND	Dan-Daura	PI	10.66168	8.026964
DAND	Dan-Daura	CI	10.66458	8.026961
DAND	Dan-Daura	PII	10.66729	8.026969
DAND	Dan-Daura	CII	10.65231	8.026872
DAND	Dan-Daura	PIII	10.66413	8.026721
DAND	Dan-Daura	CIII	10.65937	8.026964
KRMS	Kurmin-Shado	PIV	10.65314	8.036761
KRMS	Kurmin-Shado	PIV	10.68582	7.998368
KRMS	Kurmin-Shado	CV	10.68236	7.992544
KRMS	Kurmin-Shado	PV	10.68344	7.996202
KRMS	Kurmin-Shado	CVI	10.68654	7.992315
KRMS	Kurmin-Shado	PVI	10.68697	7.991673
UNG	Ungwan Noma	CVII	10.67352	7.990233
UNG	Ungwan Noma	CVII	10.65313	8.036771
UNG	Ungwan Noma	PVIII	10.67235	8.052335
UNG	Ungwan Noma	CVIII	10.6768	8.055332
UNG	Ungwan Noma	PIX	10.67626	8.056341
UNG	Ungwan Noma	CIX	10.67107	8.056357
BARWA	Barwa	PX	10.68236	7.991305
BARWA	Barwa	CX	10.68114	7.994195
BARWA	Barwa	PXI	10.68347	7.997183
BARWA	Barwa	CXI	10.68459	7.991161
BARWA	Barwa	PXII	10.68621	7.99767
BARWA	Barwa	CXII	10.68129	7.99543

P = Poultry littered sites, C = Control sites
Source: Field Survey (2024)

Soil Sampling

This study selected four farmlands with high poultry litter usage, one from each ward, to investigate soil pollution and health. Soil samples were collected at 0-30cm depth, where most physicochemical changes occur. Six soil cores (25mm diameter) were taken from each location, with surface residue removed, following standards from the Soil Health Institute (2023) and Institute of Agricultural Research (2017). Purposive and random sampling techniques were used. 24 composite samples (6 per location) were analyzed, including control samples without poultry litter. Samples were stored in zip bags and sent to the Institute's laboratory for analysis.

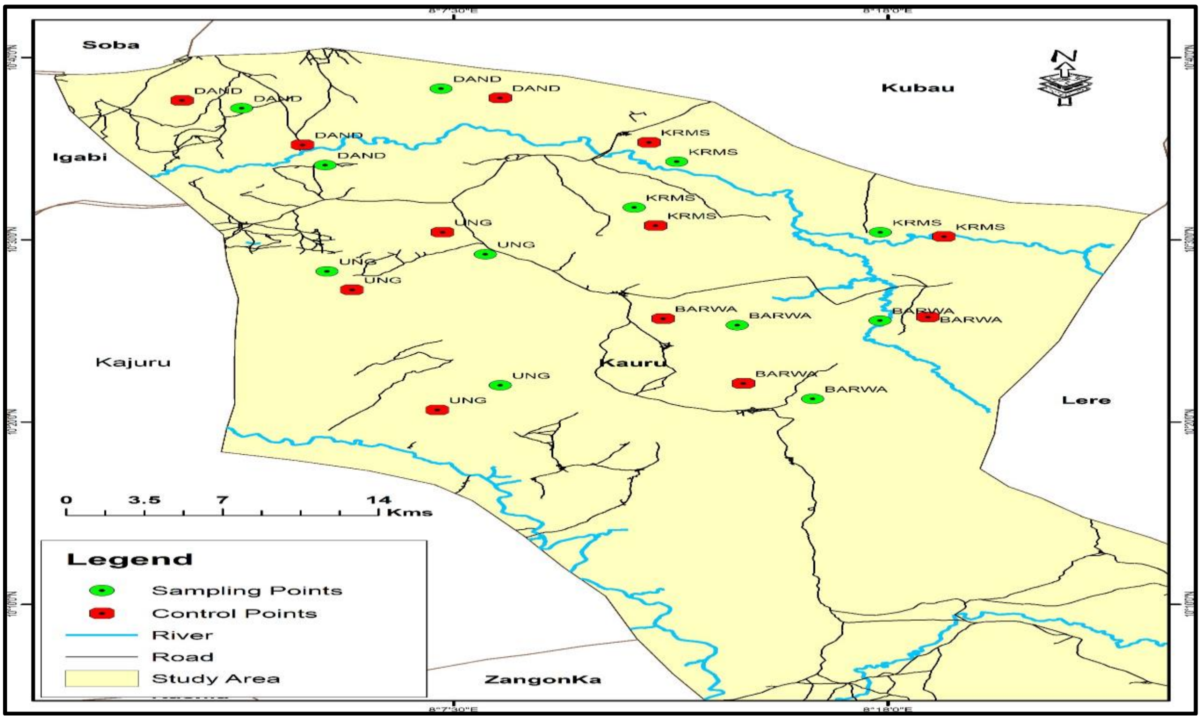

Figure 2: Sampling and Control Points in Kauru LGA, Kaduna State
Source: Field Survey (2024)

Laboratory Analysis

Soil samples labeled I-XII, air-dried, crushed, and sieved (0.5mm) at ABU's Institute of Agricultural Research soil lab, then underwent five laboratory tests, including control points, per sample.

Determination of Aggregate Stability

Soil samples (200g) were sieved (4mm, 2mm, 0.25mm, 0.212mm, 0.05mm) for particle size distribution analysis (Umar et al., 2023). A 150g subsample was submerged in water, stroked 1-minute, then washed, decanted, oven-dried, and weighed. This process assessed soil structure and water-stability of aggregates, providing insights into soil health and erosion resistance. Aggregate stability was calculated using the formula.

Aggregate stability = $(W_1, /W_0) * X_{1,2,3\ldots}$

Where, W_1 = Weight of soils retained in each sieve,

W_0 = original weight of soils used,

$X_1 = (2.0 + 0.25) / 2$ $X_2 = (0.25+0.212)/2$

$X_3 = (0.212 + 0.05)/2$ $X_4 = 0.05/2$

Mean weight diameter MWD = $\sum_{i=1}^{i=r} Pidi$

Hence, P = Proportion of soil in the sieve.

d = Average sieve diameter (Uyovbisere et al., 2013).

Soil pH Determination

Soil pH was measured using 10g of 2mm-sieved air-dried soil mixed with 25ml distilled water, 0.01M $CaCl_2$, and 1N KCl solutions. After stirring and settling, pH was read using a calibrated pH meter. Readings were recorded for each solution, providing soil pH values (IAR, 2017).

Determination of Organic Carbon (Walkley-Black Method)

Soil organic carbon was measured using the Walkley-Black method. 1g of soil was mixed with 1N $K_2Cr_2O_7$ and H_2SO_4, then heated for 30 minutes. After cooling, distilled water and indicator were added. The mixture was titrated with ammonium ferrous sulphate until color changed from greenish-yellow to purple, indicating endpoint.

OC% = (meq $K_2Cr_2O_7$ – meq $FeSO_4$) × 0.003 × 100 × F / Weight of air-dry soil taken.

Where F = correction factor (1.33) or

OC% = (blank titre – actual titre) × 0.3 × M × F / Weight of air-dry soil taken.

Where M = Conc. of ferrous ammonium sulphate

F = correction factor

OM% = % OC × 1.724.

Nitrogen Determination

Soil nitrogen was analyzed using the Kjeldahl method. 1g of soil was digested with Kjeldahl catalyst and sulfuric acid at high temperature for 2 hours. The digest was cooled, diluted, and transferred to a volumetric flask. A 10mL aliquot was distilled with NaOH, and the ammonia released was collected in boric acid with indicator. The distillate was titrated with 0.01N H_2SO_4 until color changed from green to purple, indicating the nitrogen content. (Uyovbisere et al., 2013).

CO_2 Determination

Aliquot of 0.1M KOH exposed in plastic cups for 1 – 2 hr followed by titration with standardized 0.1M HCL after the addition of saturated $BaCl_2$ solution (2 ml per 25ml KOH).

Absorbed CO_2 is calculated on the basis that 1ml of 0.1 ml HCL is equivalent to 2.2 mg CO_2 with Phenolphthalein as indicator. Table 2 shows the parameters analyzed and their standard range.

Table 2: Parameters for soil physicochemical properties determination

No	Parameter	Method of Analysis	Standard Range			Author
			Low	Medium	High	
1	Particle size distribution	Hydrometer method	<0.5	0.5-1	>1	FAO (2006); Soil Survey Staff (1975)
2	Aggregate stability	Wet sieving method (MWD)	<20	20-40	>40	Yoder (1936); Kemper (1966); Landon (1991); Soil Health Institute (2010)
3	pH	pH Electrometric Method	<5.0	5-7.5	>7.5	Soil Health Institute (2010); FAO (2006)
4	Organic Carbon	Walkley Black Method	<5.0	5-7.5	>7.5	FAO (2006); Soil Health Institute (2010)
5	Total nitrogen	Micro Keldahl Method	<0.5	0.5-1	>1	Soil Survey Staff (1975); Malgwi (2007)
6	CO_2 Determination	Volumetric Method.	<20	20-40	>40	Uyovbisere et al. (2013); Soil Health Institute (2010).
7	Organic matter	Loss on ignition (LOI)	<5.0	5-7.5	>7.5	FAO (2006); Soil Survey Staff (1975).

Source: Author's Compilation (2024)

Statistical Analysis

Descriptive statistics was used to summarize the physico-chemical properties of soil at both the control and littered site. The data generated was analyzed statistically using the Analysis of Variance (ANOVA) to compare the means of each parameter.

RESULTS AND DISCUSSION

Properties of Soil at Control and Poultry Litter Sites

This study has shown that application of poultry litter increases soil pH, making the soil less acidic. This change in pH can affect the availability of nutrients to plants and influence soil microbial activity.

The soil pH was analyzed and result as presented in Table 4 shows that with a p-value of 0.147 at Barwa, 0.215 at Ungwan Noma, 0.129 at Kurmin-Shado and 0.065 at Dan-Daura there is no statistically significant difference in the means of the soil from the treated sites and control site among the four sampling sites in the study area, (i.e., Sig.-value >0.05) which suggests that the application of poultry litter to the soil did not have a significant impact on altering the pH levels compared to the control sites in all the four sampling areas.

Soil pH (in 0.01M $CaCl_2$) p-values for the different treated farmlands were found to vary between 0.354, 0.387, 0.043 and 0.259 for Barwa, Ungwan Noma, Kurmin-Shado and Dan-Daura respectively. Only the result of Kurmin-Shado indicates that there is a statistically significant difference in the means of the treated site and the control sites.

It was observed that variation in organic matter was greater than that of organic carbon in all farmlands. The increase in organic carbon content of these soils might be due to continuous cultivation without fallow, continuous application of poultry litter, high rate of mineralization due to high temperature and crop removal for livestock feeding, fuel wood, fencing and building purposes.

Nitrogen (N) content for Barwa, Ungwan Noma and Kurmin-Shado Dan-Daura were found to be 0.06, 0.116, 0.602 and 0.042 respectively. There was a significant difference in the means of the treated soil and the control site in Dan-Daura with mean 0.042 <0.05 which means that poultry manure has a significant effect on the total nitrogen value of the area. NO_3-N, NH_3-N, NO_2-N and NH_4-NO_3 are different forms of nitrogen that are involved in the nitrogen cycle, as they are components of amino acids, proteins, nucleic acids, and other biomolecules. Nitrogen has different oxidation states and chemical properties depending on its form (Hayatsu et al., 2008).

Table 3 also revealed that poultry litter treated site's average mean for clay is 18.167%, silt is 54.21% and sand is 28.21%, while that of the control is 26.97 percent clay, 49.78 percent silt and 22.67 percent sand. The result shows that the soil texture of the study area is sandy loam and there is a significant difference in the means of the poultry litter treated soil and the control sites for clay in all the site except Kurmin Shado where the difference is not significant, silt also have a significant difference in means in all sites in the study area. Aggregate stability of soil refers to the ability of soil particles to resist disruption and maintain their structure and coherence. In other words, it measures the ability of soil aggregates to resist breaking apart and dispersing when exposed to external forces such as rainfall, wind, or tillage

Effects of Poultry Litter on Some Physico-chemical Properties of soil at the treated Site

Table 4 shows that soil pH $CaCl_2$ is positively correlated with soil pH in water (0.966) which implies that they both increase significantly and influence soil at the sites applied with poultry litter. Also from the result, soil total nitrogen increased significantly and is positively correlated to organic matter of the soil, sand is negatively correlated with silt under particle size distribution which implies that as sand increase, in the treated site, silt decrease and vise vasa. More also, organic matter content in the soil sample proves that pH value of the soil samples also influences soil fertility within the study area. Organic matter, organic carbon and soil pH value among other chemical properties are the major compound that influence soil fertility within the study area.

Table 3: Properties of Soil at Control and Poultry Littered Sites

Parameters	Barwa				Ungwan Noma				Kurmin-Shado				Dan-Daura			
	Treated soil	Control	T-Value	P-Value	Treated soil	Control	T-Value	P-Value	Treated soil	Control	T-Value	P-Value	Treated soil	Control	T-Value	P-Value
pH	6.30	5.80	1.12	0.14	7.30	6.93	0.91	0.21	7.76	6.43	5.08	0.12	6.20	5.86	3.16	0.06
pH CaCl2	5.23	5.15	0.20	0.35	6.66	6.16	0.86	0.38	7.13	5.16	4.98	0.04	5.40	4.76	5.27	0.25
O.C. g/kg	5.60	6.96	0.72	0.14	2.44	1.68	2.91	0.09	4.07	3.64	0.61	0.73	2.41	4.89	-2.76	0.10
O.M. g/kg	12.58	6.96	2.74	0.05	4.21	2.91	2.90	0.08	7.02	5.82	0.94	0.35	4.15	7.98	-2.53	0.18
TN	1.04	0.58	2.67	0.06	0.35	0.24	2.87	0.11	0.58	0.53	0.49	0.60	0.34	0.60	-1.87	0.04
NO3-N (%)	0.46	0.24	2.80	0.06	0.15	0.11	2.41	0.09	0.25	0.22	0.81	0.55	0.15	0.29	-2.39	0.17
NH3-N (%)	0.12	0.06	2.68	0.11	0.04	0.02	2.00	0.56	0.07	0.06	0.50	0.69	0.04	0.09	-2.99	0.05
NO2-N (%)	0.34	0.19	2.68	0.06	0.11	0.08	2.75	0.20	0.19	0.18	0.30	0.65	0.11	0.19	-1.51	0.03
NH4-NO3	0.29	0.16	2.72	0.06	0.10	0.07	2.77	0.32	0.16	0.15	0.45	0.88	0.09	0.20	-2.78	0.07
Clay %	26.00	19.33	0.89	0.07	19.33	13.67	2.87	0.09	16.67	18.33	-0.48	0.52	11.33	20.67	-1.98	0.09
Silt %	62.67	58.67	1.34	0.51	46.00	56.67	-1.84	0.78	51.33	56.33	-1.02	0.06	44.67	57.33	-3.96	0.32
Sand %	11.33	22.33	-1.85	0.49	34.67	32.33	0.34	0.55	32.00	24.67	2.34	0.72	44.00	24.33	2.74	0.24
CO2	68.12	61.40	0.98	0.31	66.00	66.65	-1.42	0.03	64.13	65.16	-0.89	0.03	65.26	66.00	-1.00	0.01
MWD %	1.23	1.633	-1.02	0.43	0.58	0.27	9.26	0.17	0.54	0.78	-0.68	0.08	0.50	0.58	-1.06	0.11

Source: Authors computation (2024)

STD = Standard Deviation, O.C = Organic Carbon, O.M = Organic Matter, TN = Total Nitrogen, CO2 = Carbon dioxide, MWD = MeanWeight Diameter, L = Low, M = Moderate, H = High

Table 4: Correlation Matrix Between Soil Physico-Chemical properties

	pH Water	pH CaCl2	O.C (g/kg)	O.M (g/kg)	TN (g/kg)	NO3-N(%)	NH3-N(%)	NO2-N	NH4-NO3 (%)	Clay(%)	Silt (%)	Sand(%)	CO2 Evolution	MWD
pH Water	1													
pH CaCl2	0.966*	1												
O.C (g/kg)	-0.523	-0.476	1											
O.M (g/kg)	-0.299	-0.370	0.746	1										
TN (g/kg)	-0.287	-0.365	0.751	0.994**	1									
NO3-N (%)	-0.282	-0.362	0.728	0.999**	0.995**	1								
NH3-N (%)	-0.295	-0.393	0.682	0.987*	0.972*	0.989*	1							
NO2-N (%)	-0.308	-0.391	0.752	0.981*	0.992*	0.982	0.956*	1						
NH4-NO3	-0.333	-0.421	0.735	0.996**	0.990*	0.997**	0.993*	0.976*	1					
Clay (%)	-0.220	-0.296	0.667	0.854	0.855	0.859	0.843	0.803	0.866	1				
Silt (%)	-0.429	-0.498	0.641	0.656	0.668	0.659	0.638	0.704	0.668	0.652	1			
Sand (%)	0.360	0.443	-0.741	-0.839	-0.856	-0.844	-0.814	-0.856	-0.851	-0.896	-0.910*	1		
CO2	0.142	-0.010	-0.426	0.230	0.203	0.254	0.313	0.175	0.254	0.262	0.111	-0.162	1	
MWD	-0.527	-0.451	0.888*	0.600	0.638	0.583	0.487	0.640	0.579	0.597	0.543	-0.672	-0.441	1

* Correlation is significant at the 0.05 Level (2 tailed). ** Correlation is significant at the 0.01 Level (2 tailed).

Source: Authors Analysis (2024)

pH = hydroxyl ion, O.C = Organic Carbon, O.M = Organic Matter, TN = Total Nitrogen, NO3N = Nitrate-nitrogen, NH3N = Ammonia Nitrogen, NO2N = Nitrite-Nitrogen, NH4NO3 = Ammonium Nitrate, CO2 = Carbon dioxide, MWD = Mean Weight Diameter.

Figure 3 revealed that the physico-chemical properties of the soil has changed significantly between the sites littered with poultry manure and the control site. The poultry littered sites had a mean pH of 6.89 and the control site 6.26, the organic carbon content of the poultry littered site was 3.63 and the control site 4.29, the organic matter of the poultry littered site was 6.99 and the control site was 5.92, the total nitrogen of the poultry littered site was 0.58 and the control site was 0.49, the particle size distribution or soil texture which are clay, silt and sand had mean values of 18.32%, 51.17% and 30.5% respectively at the poultry littered site and 17.99%, 57.25% and 25.92% respectively at the control site. The carbon dioxide had mean value of 65.88% at the poultry litter treated soil and 64.80% at the control site. While the aggregate stability also known as the mean weight diameter (MWD) had mean value of 0.715 at the poultry littered and 0.81775 at the control site. This result is also similar to the works of Danmaigoro et al. (2020) whose study in the Sudan Savanna of Nigeria showed that the application of poultry manure resulted in a significant increase in soil pH and had significant impact on the growth and yield of sesame varieties in the region. In acidic soils, nutrients such as iron, manganese, and phosphorus, are often locked up, a slight increase in pH as it is in this case, can make them more accessible, which is vital to soil health and productivity.

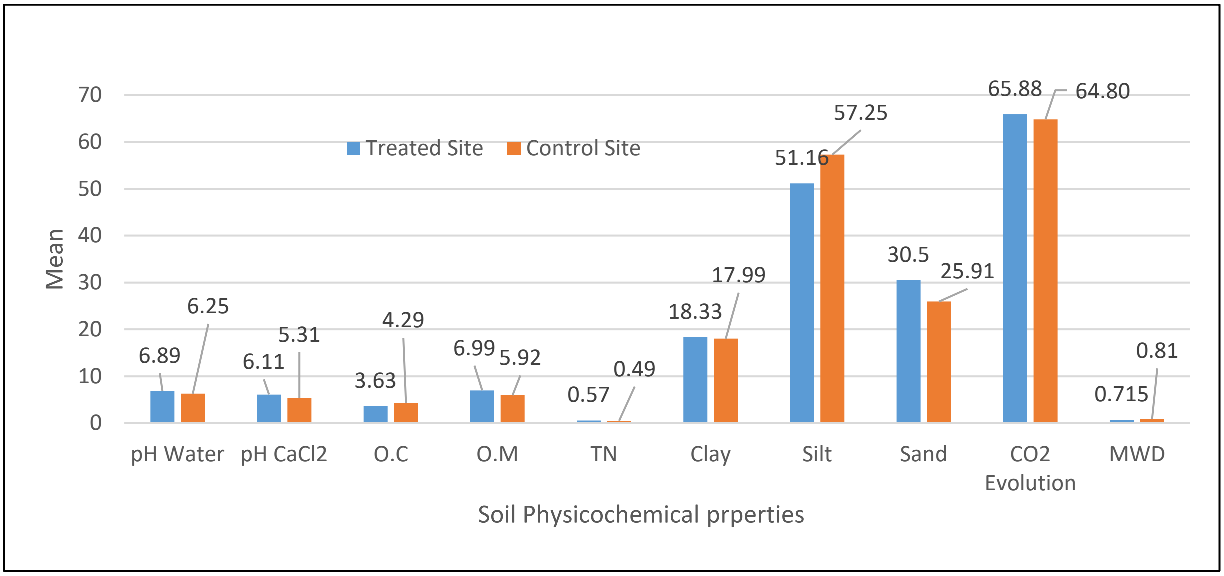

Figure 3: Comparison of Soil Properties at the Treated Site with Control Site
Source: Author's Computation (2024)

CONCLUSION

The study concludes that the continuous application of poultry manure over time alters the physico-chemical properties of the soil and has direct effect on soil health in Kauru LGA, Kaduna State. There is a significant correlation between poultry litter application and the physico-chemical properties of soil. The soil physico-chemical properties are generally below good soil health standards and there were also significant differences in the means of the poultry litter treated sites and the control sites which implies that poultry litter affects soil health.

RECOMMENDATIONS

Based on the outcome of this research, the following recommendations were made;

i. Knowledge of adequate use of poultry litter as manure should be communicated to the farmers by the agricultural extension workers, research institutions and relevant authorities in order to caution excess use and avoid future occurrence of soil degradation.
ii. Farmers should use poultry litter in conjunction with other fertilizers and soil amendments to balance nutrient inputs. Also, poultry litter should be applied at the right time and under appropriate weather conditions to minimize nutrient losses.
iii. Composting poultry litter can help reduce pathogens, weed seeds, and unpleasant odor. Hence, poultry litter should be properly composted because composted manure is less likely to pose health and environmental risks. Poultry litter should be properly fermented and crop rotation should be encouraged.

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