Nigerian Journal of Soil Science
Journal Homepage: www.soilsjournalnigeria.com

The Vertical Mobility of Nitrogen with Poultry and Sheep Manures Amendment on Degraded Ultisols in Owerri, Southeastern Nigeria

***[1]Saka, Habeebah Adewunmi, [2]Uzoho, Bethel Ugochukwu, [3]Olagunju, Solomon Oladimeji and [4]Onaolapo, Musiliat Mopelola**

[1,4]Department of Soil Science and Land Management, College of Plant Science and Crop Production, Federal University of Agriculture, P.M.B. 2240 Abeokuta, Ogun State, Nigeria.
[2]Department of Soil Science and Technology, P.M.B. 1526, School of Agriculture and Agricultural Technology, Federal University of Technology, Owerri, Imo State, Nigeria.
[3]Department of Crop Production, Faculty of Agricultural Production and Renewable Resources, P.M.B. 2022, Olabisi Onabanjo University, Ogun State, Nigeria.

Corresponding Author: sakahabeebah.staad@gmail.com; sakaha@funaab.edu.ng;
ORCID: 0000-0002-1965-8916

Abstract

Nitrogen mobility in soil is high for nitrate, causing potential leaching into groundwater and significant lost in sandy soils. This necessitates the research on the mobility of nitrogen in degraded ultisols with application of manures. A randomized complete block design experiment was conducted for two years, two locations per year and three months per location with three replications. The rates of dried, milled pure poultry and sheep manures incorporated per location at the onset of the research were 0, 30 and 60 % N. Initial soils and manures were analyzed for macro nutrients. Soil samples collected weekly, bi-weekly and monthly at soil depths (0 – 5, 5 – 10, 10 – 20 and 20 – 40 cm) for (1st, 2nd, 3rd, 4th, 6th, 8th and 12th weeks) were analyzed for total nitrogen (g kg^{-1}) using standard procedures. Applied poultry and sheep manures increased soil total N compared with control. Across the soil depths, soil total N contents decreased. Highest application of manures improved soil total N with the trend of $P_{60}S_{30} > P_{60}S_0 > P_{30}S_0 > P_{60}S_{60}$ with the values of 3.69 and 0.77 > 3.67 and 0.86 >3.62 and 0.73 > 3.47 and 0.77 across the years. Consequently, this research revealed that addition of poultry and sheep manures at 60 and 30 % N improved the soil total N which support the tropical soil fertility and sustainable agriculture. Further research is recommended to check this fact.

Keywords: Poultry manure, sheep manure, total nitrogen dynamics, Ultisols, Owerri

1. Introduction

The logical mobility flow of nitrogen globally is a complex, multi-stage and biogeochemical process characterized by the transformation of inert atmospheric nitrogen into available nitrogen. When the mobile nitrogen form (NO_3) leached away from soil, additional nutrients like organic or inorganic need to be added. Organic farming is an agricultural technique of naturally producing quality crops, vegetables, or animals without harming the environment, animals and microorganisms (Atoma *et al*., 2015; Tiwari 2023). It offers improved food security and an array of other economic, environmental, health and social advantages (UNCTAD 2008; Tiwari 2023). According to Willer and Kilcher (2011) and Gamage *et al*. 2023, organic farming is practiced in 160 countries, and 37.2 million hectares of agricultural land are managed organically.

Sustainable crop production requires the use of organic manure (Evanylo 1997; Ikeh *et al*. 2012; Imadi *et al*., 2015; Sharma *et al*., 2024). Meanwhile, the use of organic amendments to improve soil quality and fertility dates back thousands of years ago (Scotti *et al*. 2015; Omokaro *et al*., 2024). Manures are residues of plant and animal materials that are used for the purposes of increasing or restoring soil fertility (Aro and Agwu 2005; Awodun 2007; Saidia 2023). Organic fertilizers are natural materials of either plant or animal origin, which include livestock manures, green manures, crop residues, household waste, compost and woodland litter (Terry 2002; Chukwuka 2013; Khan *et al*., 2024). It includes compost, farmyard manure (FYM), slurry, worm castings, urine, peat, green manure, dried blood, bone meal, fish meal, and feather meal (Yagoub 2012; Tadewos *et al*. 2022). They are substances that when added to the soil improve the growth and quality of the plants and/ or natural products used by farmers to provide food for crops (Dipeolu and Akinbode 2005; IFPRI 2005; Kumar *et al*., 2023).

Nutrient compositions of manures depend on the types and ages of animals, feed and feed supplements, beddings, collection and storage systems, application methods, and timing of application, soil texture and weather. The nutrient content of manure changes when the feed source changes or when pasture plants change over the seasons (Lewandowski 2017). Hence, approximately 70 – 80 % of the nitrogen (N), 60 – 85 % of the phosphorus (P), and 80 – 90 % of the potassium (K) in feeds are excreted in the manure (Umass 2017).

Low soil nutrient status can be restored by adequate manure input since efficient organic manure use will alleviate the problem of declining land productivity. Organic manure is one of the inputs needed to achieve maximum yield (Cooke 2001; Verma *et al*., 2024), improve the productivity of soil and the nutritional value of crops (White *et al*. 2012). According to Porter (2004), organic manure is a source of energy for many organisms and thus helps to hold the soil minerals against leaching. Hence, the main function of manure is not only to maintain soil fertility but also to raise soil nutrients, enhance better growth, more productive and profitable farming system. It also introduces extra nutrients into the cycles of plant growth thereby increasing the yield. It provides all kinds of micro - nutrients and is able to supply 60 - 80 % of the macro - nutrients required. It could serve as a chelate (McCauley *et al*. 2009) and can bind organic micro-nutrients elements. Organic manure increases nutrient solubility and availability to plants (Clemens and Whitehurst 1990; Havlin *et al*. 1999). Organic manures are known to be rich sources of both macro and micro- nutrients of the crop. The suitability of organic manures in improving crop production has been well reported (Verma *et al*., 2024). Amendment by the use of organic manures is considered less likely to have a detrimental effect on soil physico-chemical properties. It is applicable for soil, crop growth, environment, and economic improvement (Soremi *et al*. 2017).

The application of organic manure has been found to have a higher comparative economic advantage over the use of inorganic fertilizer because of its availability (Nwajiuba and Akinsanmi 2002). Organic manures release nutrients that can be slowly stored for a long time in the soil, thereby ensuring long residual effects (Sharma and Mittra 1991; Verma *et al*., 2024). According to Singh (2021), organic materials such as farm yard manure, crop residues, water weeds and municipal wastes are suitable substitutes for inorganic fertilizers to maintain sustainable crop production and environmental quality.

Poultry manure has been reported to be an excellent source of organic manure because it contains high nitrogen, phosphorus, potassium, and other essential nutrients (Ibrahim and Abdul Rahman 2015). Sheep manure has been used in some parts of Africa to restore nutrient deficiencies in soil, promote plant growth and crop yields (Van Averbeke and De Lange 1995; Van Averbeke and Yoganathan 1997; Ayed 2002; Mhlontlo *et al*. 2006). Additions of poultry and sheep (organic) manure to the soil are accompanied by several biochemical processes due to the mineralization and immobilization of most nutrients, especially Nitrogen.

Nitrogen is the seventh most abundant element in the universe and plays a key role in the growth and development of crops (James 2013; Mysen 2019). It influences the yields mainly through leaf area expansion, which in turn, increases the amount of solar radiation interception, and dry matter production (Cam 2009; Brader 2011). Nitrogen has also been noted to be the motor to plant growth component of plant proteins and chlorophyll (Tom 2002; Fathi 2022). According to Keller (2005), nitrogen enhances vegetative growth and chloroplast formation for photosynthesis. Apart from plant nutrition, nitrogen also plays an important role in soil processes which has been a main focus of many scientific researchers (Shi *et al*. 2017; Guoce *et al*. 2018). The International Nitrogen Management System (INMS) is a global science-support system for international nitrogen policy development established as a joint activity of the United Nations Environment Programme (UNEP) and the International Nitrogen Initiative (INI).

One of the crop production problems in Southeastern Nigeria is that soils have low fertility status, highly weathered, leached, and low in organic matter and available nutrients. The addition of animal excreta would improve the soil quality. More so, vertical mobility matters in dry soils as the movement of the nutrients towards the plants roots zones needed to be determined. Consequently, this research was initiated to investigate the mobility of soil total N at various soil depths, periods and locations under different manure incorporation.

2. Materials And Methods

2.1 Research Locations

Nigeria has latitude of 9.0820° N and a longitude of 8.6753° E**.** To the north, Nigeria shares a border with Niger. Benin lies to the west of Nigeria; while Cameroon is to the east and Chad is to the northeast. Field research was conducted at the Teaching and Research farm of the Federal University of Technology, Owerri. Owerri (Latitudes 5^0 05′ and 5^0 23′ N and Longitudes 7^0 02′ and 7^0 21′ E) on an elevation of 124 meters above sea level in the degraded humid rain forest agro-ecological zone of Nigeria. The soil is classified as an Ultisol based on the United States Department of Agriculture (USDA) system of classification (Singh 2021). Its mean annual rainfall, daily temperature, and monthly relative humidity varied as 2,500 mm, 32 °C, and 85 % respectively (IPEDC 2006). Also, climatic measurements of the experimental locations were made during 2019 and 2020. Equally, the study locations were geo-referenced using a hand held Geographical Positioning System (GPS) and the coordinates as follows; Latitude 5^0 22′ 55″ N Longitude 6^0 59′ 44″ E, Latitude 5^0 22′ 23″ N Longitude 6^0 59′ 26″ E, Latitude 5^0 22′ 54″ N Longitude 6^0 59′ 32″ E and Latitude 5^0 22′ 48″ N Longitude 6^0 59′ 29″ E for the first, second, third and fourth locations respectively.

2.2 Field Experiment

Field study was conducted in four locations in two years (2019 and 2020), with each year consisting of one cycle per location. The experimental design was a 3^2 factorial replicated three times in a randomized complete block set-up and giving a total of 27 treatments (3 × 3 × 3 for poultry × sheep × replicates). Plots measuring 3 × 3 m^2 beds were constructed and treatments consisting of poultry and sheep manures were then applied.

2.3 Soil Sampling and Manure Preparations

Soil samples were collected before manure incorporation from 0 - 5, 5 - 10, 10 - 20 and 20 - 40 cm depths in each location while post-treatment soil samples were collected per treatment plots from similar depths as the former at various intervals (1^{st}, 2^{nd}, 3^{rd}, 4^{th}, 6^{th}, 8^{th} and 12^{th} weeks) in the first and second locations of 2019 and 2020. These intervals consisted of weekly in the first month, fortnightly in the second and once in the third month after treatment applications (MAT) and given a total of seven samplings per location. The treatment consisted of three rates of 0, 30 and 60 % N equivalent to 0, 1.08 and 2.16 and 0, 0.62 and 1.24 t ha^{-1} of poultry and sheep manures respectively were applied and thoroughly incorporated into the soil using spades. Both pre- and post- treatments soil samples collected were prepared by air drying, sieving using a 2 mm diameter mesh, and the fine earth fractions stored ready for laboratory analyses. The poultry and sheep manures were oven dried at 103 °C for 12 hours and ground using Wiley. They were digested using double acid.

Calculation of applied poultry manure

Amount of total N in poultry manure = 2.78 %
Let the amount of poultry manure in one hectare be "k"

- For 30 % N

2.78 % N = 100 kg poultry manure

30 % N = k

$$k = \frac{30 \times 100}{2.78}$$

$$k = \frac{3000}{2.78} \quad \text{......... eqn i}$$

k = 1,079.1367 kg of poultry manure

Using 30 % N, 1,079.1367 kg of poultry manure would be needed to be applied in one hectare

- For 60 % N

1,079.1367 × 2 = 2,158.2734 kg of poultry manure

Calculations of applied sheep manure

Amount of total N in sheep manure = 4.82 %
Let the amount of sheep manure in one hectare be "x"

- For 30 % N

4.82 % N = 100 kg sheep manure

30 % N = x

$$x = \frac{30 \times 100}{4.82}$$

$$x = \frac{3000}{4.82} \quad \text{......... eqn ii}$$

x = 622.4066 kg of sheep manure

Using 30 % N, 622.4066 kg of sheep manure would be needed to be applied in one hectare

- For 60 % N

622.4066 × 2 = 1,244.8133 kg of sheep manure

Laboratory Analyses

2.4.1 Manures, Pre - and Post Treatment Soil Analyses

The poultry and sheep manures, pre- and post-treatment soil samples were subjected to laboratory analyses using standard methods. The pretreatment soil samples were analyzed for particle size fractions after dispersion with calgon (Gee and Or 2002; Lu *et al*., 2021), pH in 1: 2.5 sample/ water ratio using the glass electrode pH meter (Jackson 1973), total N (Mulvaney 1996), EC (Richards 1954) and OC (Nelson and Sommers 1996). Also, post treatment soil samples were analyzed for total N.

2.5 Statistical Analysis

The data obtained were subjected to Analysis of Variance (ANOVA) and the means were separated using Fisher's Protected Least Significant Difference Test at a 5 % level of probability. All analyses were computed using the Genstat Statistical package (discovery edition 12 software) (Genstat 2012).

3.0 Results and Discussion

3.1 Chemical properties of the manures used for the research

The chemical properties of the poultry and sheep manures used for this research are depicted in Table 1. The manures were alkaline (Pam and Brian 2007; NRCS-USDA 2022) with a pH of 7.8 indicating promoting soil pH when applied. It has been noted that the application of organic manure can improve the soil pH (Hargreaves *et al*. 2008; Verma *et al*., 2024). Several researchers have reported an increase in soil pH with poultry and livestock manures (Iren *et al*. 2014; Li *et al*. 2018; Verma *et al*., 2024). Electrical conductivity was higher in poultry (14.23) than sheep (9.45 dS m^{-1}) indicating the tendency of high salt concentration in the former than later.

The total sodium contents of poultry and sheep manures recorded 0.89 and 0.79 g kg^{-1} indicating more than 10 % higher in the former. Concentrations of nutrients such as N, P and K were higher in poultry manure while Ca, Mg and organic carbon were higher in sheep manure indicating variation in the nutrient contributions to the soils. The nutrients and pH concentrations in the manures (Table 1) relative to the soil (Table 2) show that the application to the soil could promote it. Pam and Brian (2007) and NRCS-USDA (2022) classified pH range of between 7.4 – 7.8 as mildy alkaline and suggesting that the manures were alkaline in reaction. It is well known that poultry manure has a higher nutritional value than sheep manure (Abdelrazzak 2002; Agbede 2025).

The EC values of both manures were above 3.2 dS m^{-1} classified as very strongly saline by LAS (2014). Its higher value in poultry manure than sheep manure could be due to the high soluble salt contents and as such might increase the salt contents of applied soils. Other researchers have also noted higher EC values of poultry manure than cattle and goat manure (Azeez and Van Averbeke 2010[b]; Usman 2015; Saka *et al*. 2017; Fathi 2022). The higher sodium content of poultry manure than sheep manure could be responsible for its high EC value.

Nutrient concentrations especially total N, P and K were better in poultry than sheep manure with the values equivalent to 89.66, 4.68 and 9.13 g kg^{-1} in poultry manure and 83.36, 4.22 and 8.93 g kg^{-1} of sheep manure. This followed the findings of (Usman 2015; Harishma *et al*., 2025), who stated that the fertility status of the soil proved to be beneficial, with poultry manure than any other organic manure in his research. Conversely, sheep manure was higher in calcium, magnesium and organic carbon with values equivalent to 6.92, 5.69 and 515.44 g kg^{-1} in sheep and 6.89, 5.64 and 298.98 g kg^{-1} in poultry manure. Sheep manure increased soil organic matter and soil CEC, and therefore the soil nutrient retention capacity. Mixing manure with sandy soils helps to retain moisture levels. Manure produces increased soil carbon, which is an important source of energy that makes nutrients available to plants. It reduced runoff and leaching of nitrates in the soil (Osama *et al*. 2016; Watts *et al*., 2023).

Variations in the composition of poultry and sheep manures could be due to differences in the feed intake. Sheep diet was composed of roughages whereas, poultry consisted mainly of concentrates. Sheep manure application improves soil properties by improving physiochemical and biological conditions of the soil. Sheep manure increased soil available N. The impact of diet in the manures was demonstrated by the high organic carbon and C: N contents of sheep relative to poultry manure due to its carbonaceous nature (Osama *et al*.

2016). A C: N ratio of less than 30 had been noted to portend net N mineralization of soils

Table 1: Nutrients Composition of Poultry and Sheep Manures Applied.

Chemical Properties	Manures	
	Poultry	Sheep
PH	7.8	7.8
EC (dS m^{-1})	14.23	9.45
Total nitrogen (g kg^{-1})	89.66	83.36
Total – phosphorus (g kg^{-1})	4.68	4.22
Total potassium (g kg^{-1})	9.13	8.93
Total sodium (g kg^{-1})	0.89	0.79
Total – calcium (g kg^{-1})	6.89	6.92
Total magnesium (g kg^{-1})	5.64	5.69
Organic carbon (g kg^{-1})	298.98	515.44
Carbon: Nitrogen	3.34	6.18
Exchangeable acidity ($cmol^{+}$ kg^{-1})	0.6	0.6

(Sylvia *et al*. 2004), indicating the ability of the manures to promote soil N contents. Generally, both manure properties (Table 1) were better than those of the soils (Table 2a and 2b), suggesting their ability to improve soil fertility on application.

3.2 Physico- chemical Properties of Initial Soils Used for the Research.

The Physico- chemical properties of the experimental soils in first and second locations in 2019 and 2020 are shown in Tables 2a and 2b, respectively. In Table 2a, sand, silt and clay contents ranged from 682.00 – 701.00, 41.00 – 48.00 and 25.70 – 28.80 and 726.00 – 741.00, 18.00 – 26.00 and 23.80 – 25.30 g kg^{-1} in first and second locations of 2019, respectively. In both locations, the distribution of the various soil particles was inconsistent with soil depths and with mean concentrations being an increasing order of sand > clay > silt, the texture of the soils between sandy loam and loam sandy in the first and second locations, respectively.

In Table 2b, ranges of sand, silt and clay were respectively 886.00 – 912.00, 42.00 – 72.00 and 28.00 - 62.00 (first) and 884.00 – 902.00, 54.00 – 62.00 and 40.00 – 62.00 g kg^{-1} (second locations), with their distributions down soil depths inconsistent for all fractions in the first location and increase for sand, decrease for silt and inconsistent for clay in second location. In both locations and years, mean soil fractions decreased in the order sand > silt > clay with sand better than others. Generally, the texture of the soils in both years (2019 and 2020) and locations (first and second), was dominantly sandy, probably due to the nature of the parent material which is Coastal plain sand (Uzoho 2010; Lu *et al*., 2021). In each location, sand content decreased while clay increased with soil depths and with the trend of clay being due to the illuviation process.

Table 2a: Selected Physico-chemical Properties of the Soils Studied in Early and Late Seasons of 2019.

	Wet Season 2019					Dry Season 2019				
	Soil Depths (cm)					Soil Depths (cm)				
Physico chemical properties	0 - 5	0 - 10	10 - 20	20 - 40	Mean	0 - 5	0 - 10	10 - 20	20 - 40	Mean
Sand (g kg^{-1})	682	680	701	684	686.75	726	741	738	728	733.25
Silt (g kg^{-1})	46	41	42	48	44.25	21	18	24	26	22.25
Clay (g kg^{-1})	27.2	27.1	25.7	28.8	27.2	25.3	24.1	23.8	24.6	24.45
Textural Class			sandy loam					Loamy sand		
pH	4.8	4.4	4.1	4.5	4.45	4.6	4.5	4.4	4.5	4.5
EC (d Sm^{-1})	0.2	0.2	0.2	0.1	0.175	0.3	0.3	0.2	0.2	0.25
Total N (g kg^{-1})	1.99	2.07	2.05	1.99	2.025	1.79	1.7	1.77	1.71	1.74
OC (g kg^{-1})	6.10	6.30	6.10	6.00	6.13	5.42	5.21	5.38	5.26	5.32

Table 2b: Selected Physico-chemical Properties of the Soils Studied in Early and Late Seasons of 2020.

	Wet Season 2020					Dry Season 2020				
	Soil Depths (cm)					Soil Depths (cm)				
Physico chemical properties	0 - 5	0 - 10	10 - 20	20 - 40	Mean	0 - 5	0 - 10	10 - 20	20 - 40	Mean
Sand (g kg^{-1})	906	904	912	886	902.00	886	884	894	902	891.50
Silt (g kg^{-1})	66	48	42	72	57.00	62	58	58	54	58.00
Clay (g kg^{-1})	28	52	42	62	46.00	52	62	40	48	50.50
Textural Class			Sand					Loamy sand		
pH	4.53	4.87	4.76	4.45	4.65	4.03	4.07	4.23	4.33	4.17
EC (d Sm^{-1})	0.4	0.4	0.3	0.2	0.33	0.3	0.3	0.2	0.2	0.25
Total N (g kg^{-1})	0.8	0.7	0.7	0.6	0.70	0.9	1.1	0.9	0.8	0.93
OC (g kg^{-1})	11.30	9.30	8.20	7.90	9.18	13.20	13.60	10.60	10.50	11.98

From the result in Table 2a (2019), Soil pH, EC and total N ranged respectively from 4.10 – 4.80, 0.10 - 0.20 dS m^{-1} and 1.99 – 2.07 g kg^{-1} (first location) and 4.4 – 4.6, 0.20 - 0.20 dS m^{-1} and 1.70 – 1.79 g kg^{-1} (second location) (Table 2a). While the ranges in 2020 (Table 2b) were 4.45 – 4.87, 0.20 - 0.40 dS m^{-1} and 0.60 – 0.80 g kg^{-1} in the first location and 4.03 – 4.33, 0.20 - 0.30 dS m^{-1} and 0.80 – 1.10 g kg^{-1} in the second location (Table 2a). However, the values for soil pH indicated that they were slightly – moderately acidic (Adaikwu and Ali 2013; NRCS-USDA 2022) with the degree greater down soil depth, this could be due to its poor organic matter content. It has been reported that the poorer the soil organic matter, the higher the soil acidity (Hargreaves *et al*. 2008; Hassan *et al*., 2023) as decaying organic matter produces H^+ which is responsible for acidity. In both locations and years, values of the soil pH were below 5.0. This shows that the soils may suffer from aluminum toxicity since this occurs in soils with a pH less than 5.0 and increases as pH decreases (Neenu and Karthika 2019). However, lower values than pH 5 also suggested that all volatile fatty acids were evaporated and this would be constrained by high acidity and poor fertility status (Obiefuna *et al*. 2012; Atasoy and Cetecioglu 2022). In both locations in 2019, the pH decreased down soil depth up to 10 – 20 cm and it could be a result of depressed organic matter content that has been noted in soil which is increasingly related to its pH (Prasad and Chakraborty 2019). While that of 2020 was not consistent.

The mean pH of the soils resulted to 4.45, 4.50, 4.65 and 4.17 in the first and second locations of 2019 and 2020 respectively, giving a range of 4.17 – 4.65. This showed that the soils were slightly acidic (Adaikwu and Ali 2013; NRCS-USDA 2022). and might suffer from aluminum toxicity since this occurs in soils with pH less than 5.00 and increases in intensity as the value decreases below this value (Uzoho *et al*. 2022). The electrical conductivity decreased with depth with mean values varying as 0.18 - 0.25 d Sm^{-1} in the first and second locations of 2019 and 0.25 – 0.33 d Sm^{-1} also in both locations of 2020. The range of 0.18 – 0.33 d Sm^{-1} indicates low salt content of the soils and this might not constitute a threat to its productivity.

The distribution of total N down soil depth was not consistent in the first and second seasons of 2019 but decreased with depth in both locations in 2020. Mean values were 1.74 – 2.03 and 0.70 – 0.93 g kg^{-1} in both locations of 2019 and 2020 respectively, with those of 2019 greater than 2020. Mean concentrations of both locations and years were low compared to the critical value of 12.50 g kg^{-1} for Southeastern Nigerian soils (Cooke 2001; Ononogbo *et al*., 2024), indicating N deficiency in the soils. The concentrations of OC were low (Enwezor *et al*. 1990; Adaikwu and Ali 2013).

Generally, the soils could be described as coarse, textured, acidic, non- saline, low in organic matter, and thus poor in fertility consistent with Ultisols of Southeastern Nigeria (Enwezor *et al*. 1990; Uzoho *et al*. 2016). Sustained crop production in the soils could therefore be achieved through the addition of external amendments, especially organic manures.

3.3 Soil Total Nitrogen

Total nitrogen increased significantly ($p \leq 0.05$) with manures relative to the control at various soil depths and weeks after treatments (WAT) in the first and second locations of 2019 and 2020 (Table 3). Also, it was better with 60 than 30 % N of both poultry and sheep manures only. The increased concentrations with manures could be due to high N content of the manures (Table 1). Other researchers have reported high nutrient especially N content, with organic manure applications (Zhao *et al*. 2017; Saka *et al*. 2017; Guoce *et al*. 2018; Saka *et al*., 2023[a,b]). Mean total N averaged over soil depths and applied manures varied in weeks after application in the first and second locations of the years.

However, its concentrations using only poultry manures were 3.35 and 3.15, 3.74 and 3.07, 3.43 and 3.02, 3.53 and 3.58, 3.40 and 2.85, 3.56 and 3.48 and 3.67 and 3.23 g kg^{-1} in 2019 and 1.00 and 0.82, 0.94 and 0.90, 0.83 and 0.89, 1.11 and 1.02, 1.02 and 0.97, 1.01 and 0.96 and 1.04 and 0.90 g kg^{-1} in 2020 for the control, 3.36 and 3.20, 3.82 and 3.15, 3.45 and 3.12, 3.55 and 3.70, 3.48 and 2.90, 3.67 and 3.59 and 3.68 and 3.30 g kg^{-1} in 2019 and 1.22 and 0.95, 0.95 and 0.97, 1.09 and 0.97, 0.96 and 1.07, 1.15 and 1.03, 1.08 and 1.04 and 1.14 and 0.95 in g kg^{-1} 2020 for 30 % N poultry manure and 3.37 and 3.31, 3.79 and 3.17, 3.47 and 3.11, 3.76 and 1.25, 3.48 and 2.99, 3.54 and 2.92 and 3.69 and 3.35 g kg^{-1} in 2019 and 1.06 and 0.76, 1.00 and 0.98, 0.99 and 1.00, 0.94 and 0.95, 0.94 and 0.95 and 0.97 and 0.85 g kg^{-1} in 2020 for 60 % N poultry manure in wet and dry seasons at 1st, 2nd, 3rd, 4th, 6th, 8th and 12th WAT respectively.

Total N averaged over soil depths with sheep manures only includes 3.29 and 3.17, 3.58 and 3.08, 3.44 and 3.09, 3.58 and 3.67, 3.46 and 2.91, 3.56 and 3.52 and 3.64 and 3.23 g kg^{-1} (2019), 1.03 and 0.80, 0.89 and 0.91, 0.91 and

0.89, 0.86 and 0.91, 0.92 and 0.89, 0.90 and 0.91 and 0.94 and 0.81 (2020) for the control, 3.39 and 3.27, 3.79 and 3.20, 3.45 and 3.12, 3.53 and 3.74, 3.45 and 2.85, 3.60 and 3.54 and 3.69 and 3.36 (2019) and 1.11 and 0.81, 0.99 and 0.93, 0.94 and 1.00, 1.37 and 1.09, 0.99 and 0.96, 0.96 and 0.96 and 1.00 and 0.86 (2020) for 30 % N and 3.38 and 3.19, 3.79 and 3.11, 3.47 and 3.04, 3.56 and 3.65, 3.45 and 2.98, 3.62 and 3.58 and 3.70 and 3.38 (2019) and 1.15 and 0.92, 1.00 and 0.98, 1.07 and 0.98, 1.09 and 1.16, 1.19 and 1.09, 1.16 and 1.05 and 1.21 and 1.02 g kg^{-1} (2020) for 60 % N in first and second locations of 1^{st}, 2^{nd}, 3^{rd}, 4^{th}, 6^{th}, 8^{th} and 12^{th} WAT respectively. This showed that irrespective of soil depths, total N was better in the first than the second locations and in 2019 than in 2020 for various weeks after manure applications probably due to the favorable conditions for N mineralization in the soils. More so, soil total N was better in the first location relative to second location in both years and this could be as a result of volatilization of NH_3^+ during dry seasons (second location) (Maynard 2015; Liu *et al*., 2025). The total N in 2019 was moderate while that of 2020 was low (Hill 2001). The low total N in 2020 compared with 2019 could be attributed to low rainfall during the experimental periods. The results confirm that manure application increased soil nitrogen and that nitrogen concentration decreased with depth, which aligns with expectations of root uptake by plants.

Table 3: Total Nitrogen at various Soil Depths and Weeks After Manure Application (WAMA) in Wet and Dry Seasons of 2019 and 2020

Years and Seasons	2019 a				2019 b				2020 a				2020 b			
Soil Depths	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Manure Rates	First Week After Manure Application															
P_0S_0	3.43	3.31	2.99	3.10	3.03	2.97	3.02	3.12	1.09	1.06	0.68	0.65	0.75	0.68	0.70	0.76
P_0S_{30}	3.60	3.43	3.33	3.25	3.18	3.05	3.17	3.19	1.15	1.12	0.97	0.78	0.82	0.80	0.83	0.94
P_0S_{60}	3.53	3.44	3.34	3.39	3.28	3.19	3.29	3.32	1.18	1.14	1.27	0.89	0.84	0.97	0.85	0.94
Mean	**3.52**	**3.39**	**3.22**	**3.25**	**3.16**	**3.07**	**3.16**	**3.21**	**1.14**	**1.11**	**0.97**	**0.77**	**0.80**	**0.82**	**0.79**	**0.88**
$P_{30}S_0$	3.62	3.36	3.18	3.19	3.22	3.14	3.18	3.20	1.50	1.43	1.04	0.73	1.13	0.74	0.68	0.91
$P_{30}S_{30}$	3.67	3.40	3.25	3.17	3.33	3.25	3.30	3.33	1.14	1.10	1.45	0.89	0.80	1.15	0.93	0.98
$P_{30}S_{60}$	3.67	3.44	3.01	3.32	3.13	3.03	3.15	3.16	1.67	1.63	1.24	0.83	1.33	0.94	0.86	0.97
Mean	**3.65**	**3.40**	**3.15**	**3.23**	**3.23**	**3.14**	**3.21**	**3.23**	**1.44**	**1.39**	**1.24**	**0.82**	**1.09**	**0.94**	**0.82**	**0.95**
$P_{60}S_0$	3.62	3.39	3.05	3.28	3.46	3.40	3.35	3.31	1.20	1.18	1.12	0.68	0.88	0.82	0.73	0.88
$P_{60}S_{30}$	3.69	3.45	3.19	3.28	3.38	3.33	3.35	3.39	1.44	1.40	1.04	0.80	0.10	0.74	0.82	0.83
$P_{60}S_{60}$	3.47	3.42	3.23	3.33	3.20	3.11	3.17	3.24	1.13	1.10	0.87	0.76	0.80	0.84	0.77	0.94
Mean	**3.59**	**3.42**	**3.16**	**3.30**	**3.35**	**3.28**	**3.29**	**3.31**	**1.26**	**1.23**	**1.01**	**0.75**	**0.59**	**0.80**	**0.77**	**0.88**
S_0	3.56	3.35	3.07	3.19	3.24	3.17	3.18	3.21	1.26	1.22	0.95	0.69	0.92	0.75	0.70	0.85
S_{30}	3.65	3.43	3.26	3.23	3.30	3.21	3.27	3.30	1.24	1.21	1.15	0.82	0.57	0.90	0.86	0.92
S_{60}	3.56	3.43	3.19	3.35	3.20	3.11	3.20	3.24	1.33	1.29	1.13	0.83	0.99	0.92	0.83	0.95
LSDs (0.05) P	*0.05*	*0.08*	*0.07*	*0.11*	*0.06*	*0.02*	*0.04*	*0.02*	*0.01*	*0.04*	*0.01*	*0.07*	*0.04*	*0.03*	*0.06*	*0.09*
" S	*0.05*	*0.08*	*0.07*	*0.11*	*0.06*	*0.02*	*0.04*	*0.02*	*0.01*	*0.04*	*0.01*	*0.07*	*0.04*	*0.03*	*0.06*	*0.09*
' P x S	*0.08*	*0.14*	*0.12*	*0.19*	*0.10*	*0.03*	*0.08*	*0.04*	*0.02*	*0.07*	*0.01*	*0.11*	*0.07*	*0.05*	*0.09*	*0.16*
	Second Week After Manure Application															
P_0S_0	3.59	3.65	3.71	3.69	3.07	3.07	2.66	3.08	0.77	0.61	0.78	0.78	0.72	0.88	0.83	0.83
P_0S_{30}	3.77	3.76	3.74	3.73	3.38	3.17	2.92	3.17	0.96	0.92	1.38	0.81	0.89	0.87	0.86	0.96
P_0S_{60}	3.67	3.79	3.84	3.92	3.18	3.06	2.85	3.26	0.94	0.85	1.23	1.19	0.89	1.01	1.19	0.85
Mean	**3.68**	**3.73**	**3.76**	**3.78**	**3.21**	**3.10**	**2.81**	**3.17**	**0.89**	**0.79**	**1.13**	**0.93**	**0.83**	**0.92**	**0.96**	**0.88**
$P_{30}S_0$	3.61	3.76	3.83	3.96	3.45	3.35	2.78	3.14	0.10	1.02	0.91	1.27	0.87	0.90	0.92	1.08
$P_{30}S_{30}$	3.93	3.89	3.81	3.81	3.39	3.18	3.12	3.25	1.20	1.16	0.95	0.95	1.05	0.98	1.00	1.07
$P_{30}S_{60}$	3.83	3.76	3.80	3.88	3.19	3.07	2.70	3.15	1.08	1.01	0.87	0.83	0.93	0.94	0.88	1.05
Mean	**3.79**	**3.80**	**3.81**	**3.88**	**3.34**	**3.20**	**2.87**	**3.18**	**0.79**	**1.06**	**0.91**	**1.02**	**0.95**	**0.94**	**0.93**	**1.07**
$P_{60}S_0$	3.87	3.86	3.83	3.91	3.18	3.11	2.78	3.25	1.07	0.98	1.23	1.20	0.87	0.99	1.10	0.97
$P_{60}S_{30}$	3.73	3.74	3.78	3.76	3.31	3.18	3.04	3.30	0.92	0.84	0.89	0.88	0.76	0.89	0.93	0.93
$P_{60}S_{60}$	3.70	3.77	3.72	3.82	3.32	3.22	3.11	3.19	1.18	1.16	0.79	0.89	1.05	0.89	0.90	1.15
Mean	**3.77**	**3.79**	**3.78**	**3.83**	**3.27**	**3.17**	**2.98**	**3.25**	**1.06**	**0.99**	**0.97**	**0.99**	**0.89**	**0.92**	**0.98**	**1.02**
S_0	3.69	3.76	3.79	3.85	3.23	3.18	2.74	3.16	0.65	0.87	0.97	1.08	0.82	0.92	0.95	0.96
S_{30}	3.81	3.80	3.78	3.77	3.36	3.18	3.03	3.24	1.03	0.97	1.07	0.88	0.90	0.91	0.93	0.99
S_{60}	3.73	3.77	3.79	3.87	3.23	3.12	2.89	3.20	1.07	1.01	0.96	0.97	0.96	0.95	0.99	1.02
LSDs (0.05) P	*0.02*	*0.03*	*0.05*	*0.02*	*0.01*	*0.09*	*0.15*	*0.06*	*0.04*	*0.01*	*0.01*	*0.05*	*0.07*	*0.09*	*0.13*	*0.09*
" S	*0.02*	*0.03*	*0.05*	*0.02*	*0.01*	*0.09*	*0.15*	*0.06*	*0.04*	*0.01*	*0.01*	*0.05*	*0.07*	*0.09*	*0.13*	*0.09*
' P x S	*0.04*	*0.06*	*0.09*	*0.03*	*0.02*	*0.15*	*0.25*	*0.10*	*0.07*	*0.01*	*0.02*	*0.09*	*0.12*	*0.17*	*0.22*	*0.15*

a = wet season, b = dry season, 1 = 0-5 cm, 2 = 5-10 cm, 3 = 10-20 cm, 4 = 20-40 cm depths, P =poultry, S = sheep and P x S = poultry and sheep manure interactions.

Table 3 Cont'd

Years and Seasons	2019 a				2019 b				2020 a				2020 b			
Soil Depths	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Manure Rates	Third Week After Manure Application															
P_0S_0	3.49	3.38	3.32	3.27	3.02	3.00	2.95	2.77	0.72	0.79	0.80	0.63	0.77	0.76	0.78	0.81
P_0S_{30}	3.56	3.46	3.32	3.38	3.33	3.12	3.00	2.97	0.97	1.07	0.87	0.75	0.94	0.93	0.95	1.21
P_0S_{60}	3.66	3.52	3.46	3.37	3.11	3.01	3.04	2.89	0.95	0.88	0.86	0.69	0.86	0.89	0.86	0.94
Mean	**3.57**	**3.45**	**3.37**	**3.34**	**3.15**	**3.04**	**3.00**	**2.88**	**0.88**	**0.91**	**0.84**	**0.69**	**0.86**	**0.86**	**0.86**	**0.99**
$P_{30}S_0$	3.64	3.36	3.51	3.44	3.40	3.29	3.22	3.13	1.18	1.19	0.96	0.75	1.06	0.96	0.95	0.86
$P_{30}S_{30}$	3.59	3.40	3.39	3.37	3.22	3.12	3.09	3.00	1.17	1.01	0.90	0.76	0.91	0.96	0.96	1.09
$P_{30}S_{60}$	3.65	3.44	3.29	3.28	3.14	3.00	2.97	2.80	1.17	2.11	1.18	0.68	1.07	0.99	0.88	0.89
Mean	**3.63**	**3.40**	**3.40**	**3.36**	**3.25**	**3.14**	**3.09**	**2.98**	**1.17**	**1.44**	**1.01**	**0.73**	**1.01**	**0.97**	**0.93**	**0.95**
$P_{60}S_0$	3.67	3.39	3.41	3.34	3.13	3.07	3.01	3.04	1.11	1.04	0.87	0.82	0.90	0.91	1.00	0.90
$P_{60}S_{30}$	3.56	3.58	3.48	3.30	3.26	3.13	3.11	3.11	1.03	1.04	0.87	0.77	0.91	0.92	0.97	1.19
$P_{60}S_{60}$	3.62	3.42	3.49	3.41	3.30	3.18	3.11	2.88	1.32	1.35	0.92	0.74	1.18	0.96	0.94	1.25
Mean	**3.62**	**3.46**	**3.46**	**3.35**	**3.23**	**3.13**	**3.08**	**3.01**	**1.15**	**1.14**	**0.89**	**0.78**	**1.00**	**0.93**	**0.97**	**1.11**
S_0	3.60	3.38	3.41	3.35	3.18	3.12	3.06	2.98	1.00	1.01	0.88	0.73	0.91	0.88	0.91	0.86
S_{30}	3.57	3.48	3.40	3.35	3.27	3.12	3.07	3.03	1.06	1.04	0.88	0.76	0.92	0.94	0.96	1.16
S_{60}	3.64	3.46	3.41	3.35	3.18	3.06	3.04	2.86	1.15	1.45	0.99	0.70	1.04	0.95	0.89	1.03
LSDs (0.05) P	*0.06*	*0.07*	*0.02*	*0.04*	*0.07*	*0.09*	*0.09*	*0.07*	*0.19*	*0.01*	*0.11*	*0.06*	*0.03*	*0.07*	*0.07*	*0.07*
" S	*0.06*	*0.07*	*0.02*	*0.04*	*0.07*	*0.09*	*0.09*	*0.07*	*0.19*	*0.01*	*0.11*	*0.06*	*0.03*	*0.07*	*0.07*	*0.07*
' P x S	*0.10*	*0.12*	*0.04*	*0.07*	*0.12*	*0.16*	*0.16*	*0.11*	*0.33*	*0.01*	*0.20*	*0.10*	*0.05*	*0.12*	*0.12*	*0.12*
	Fourth Week After Manure Application															
P_0S_0	3.57	3.39	3.27	3.56	3.50	3.50	3.44	3.41	0.86	0.81	0.78	0.76	0.79	0.79	0.83	0.93
P_0S_{30}	3.60	3.49	3.32	3.77	3.80	3.75	3.67	3.54	1.51	1.51	1.49	1.49	1.21	1.19	0.86	1.17
P_0S_{60}	3.70	3.55	3.40	3.71	3.72	3.66	3.54	3.43	1.09	1.04	1.01	0.96	0.97	0.97	1.19	1.28
Mean	**3.62**	**3.48**	**3.33**	**3.68**	**3.67**	**3.64**	**3.55**	**3.46**	**1.15**	**1.12**	**1.09**	**1.07**	**0.99**	**0.98**	**0.96**	**1.13**
$P_{30}S_0$	3.67	3.59	3.46	3.63	3.77	3.81	3.81	3.70	0.94	0.85	0.79	0.78	0.85	0.80	0.92	1.11
$P_{30}S_{30}$	3.63	3.55	3.35	3.62	3.77	3.73	3.65	3.55	1.20	1.19	1.14	1.11	1.01	1.03	1.00	1.18
$P_{30}S_{60}$	3.58	3.49	3.33	3.69	3.78	3.70	3.64	3.52	0.94	0.91	0.85	0.83	0.91	1.85	0.88	1.29
Mean	**3.63**	**3.54**	**3.38**	**3.65**	**3.77**	**3.75**	**3.70**	**3.59**	**1.03**	**0.98**	**0.93**	**0.91**	**0.92**	**1.23**	**0.93**	**1.19**
$P_{60}S_0$	3.69	3.53	3.89	3.72	3.87	3.81	3.76	3.59	0.94	0.96	0.93	0.91	0.94	0.93	1.10	0.97
$P_{60}S_{30}$	3.64	3.53	3.27	3.59	3.94	3.89	3.80	3.71	1.20	1.55	1.53	1.54	1.18	1.23	0.93	1.13
$P_{60}S_{60}$	3.68	3.55	3.36	3.74	3.80	3.75	3.65	3.55	0.94	1.53	1.49	1.48	1.30	1.17	0.90	1.18
Mean	**3.67**	**3.54**	**3.51**	**3.68**	**3.87**	**3.82**	**3.74**	**3.62**	**1.03**	**1.35**	**1.32**	**1.31**	**1.14**	**1.11**	**0.98**	**1.09**
S_0	3.64	3.50	3.54	3.64	3.71	3.71	3.67	3.57	0.91	0.87	0.83	0.82	0.86	0.84	0.95	1.00
S_{30}	3.62	3.52	3.31	3.66	3.84	3.79	3.71	3.60	1.30	1.42	1.39	1.38	1.13	1.15	0.93	1.16
S_{60}	3.65	3.53	3.36	3.71	3.77	3.70	3.61	3.50	0.99	1.16	1.12	1.09	1.06	1.33	0.99	1.25
LSDs (0.05) P	*0.05*	*0.06*	*0.03*	*0.05*	*0.05*	*0.05*	*0.08*	*0.12*	*0.07*	*0.06*	*0.01*	*0.05*	*0.07*	*0.04*	*0.05*	*0.11*
" S	*0.05*	*0.06*	*0.03*	*0.05*	*0.05*	*0.05*	*0.08*	*0.12*	*0.07*	*0.06*	*0.01*	*0.05*	*0.07*	*0.04*	*0.05*	*0.11*
' P x S	*0.08*	*0.09*	*0.06*	*0.08*	*0.09*	*0.08*	*0.13*	*0.20*	*0.13*	*0.10*	*0.02*	*0.09*	*0.13*	*0.06*	*0.08*	*0.18*

a = first location, b = second locations, 1 = 0-5 cm, 2 = 5-10 cm, 3 = 10-20 cm, 4 = 20-40 cm depths, P =poultry, S = sheep and P x S = poultry and sheep manure interactions.

Table 3 Cont'd

Years and Seasons	2019 a				2019 b				2020 a				2020 b			
Soil Depths	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Manure Rates	Sixth Week After Manure Application															
P_0S_0	3.59	3.45	3.14	3.12	2.96	2.84	2.74	2.59	0.94	0.96	0.89	0.54	0.84	0.89	0.55	0.87
P_0S_{30}	3.61	3.49	3.19	3.39	2.98	2.90	2.78	2.72	1.19	1.05	0.93	0.68	1.03	0.96	0.78	1.03
P_0S_{60}	3.72	3.61	3.33	3.19	3.03	2.97	2.90	2.79	1.03	1.41	1.34	1.26	1.15	1.17	1.16	1.16
Mean	**3.64**	**3.52**	**3.22**	**3.23**	**2.99**	**2.90**	**2.81**	**2.70**	**1.05**	**1.14**	**1.05**	**0.83**	**1.01**	**1.01**	**0.83**	**1.02**
$P_{30}S_0$	3.70	3.62	3.47	3.30	3.01	2.93	2.88	2.78	1.19	1.14	1.04	0.72	1.07	1.01	0.78	1.01
$P_{30}S_{30}$	3.61	3.54	3.28	3.47	3.01	2.91	2.83	2.63	1.30	1.24	1.18	0.84	1.07	1.12	0.84	1.01
$P_{30}S_{60}$	3.64	3.54	3.31	3.26	3.10	3.05	2.97	2.72	1.55	1.41	1.34	0.79	1.21	1.25	0.82	1.14
Mean	**3.65**	**3.57**	**3.35**	**3.34**	**3.04**	**2.96**	**2.89**	**2.71**	**1.35**	**1.26**	**1.19**	**0.78**	**1.12**	**1.13**	**0.81**	**1.05**
$P_{60}S_0$	3.69	3.57	3.39	3.50	3.14	3.09	3.09	2.82	1.03	1.00	0.94	0.68	1.00	0.97	0.78	0.94
$P_{60}S_{30}$	3.66	3.45	3.22	3.45	3.11	2.91	2.76	2.68	1.00	0.94	0.91	0.62	0.94	0.91	0.78	0.98
$P_{60}S_{60}$	3.74	3.57	3.18	3.32	3.21	3.13	3.03	2.89	1.18	1.12	1.03	0.85	1.06	1.06	0.85	1.07
Mean	**3.70**	**3.53**	**3.26**	**3.42**	**3.15**	**3.04**	**2.96**	**2.80**	**1.07**	**1.02**	**0.96**	**0.72**	**1.00**	**0.98**	**0.80**	**1.00**
S_0	3.66	3.55	3.33	3.31	3.04	2.95	2.90	2.73	1.05	1.03	0.96	0.65	0.97	0.96	0.70	0.94
S_{30}	3.63	3.49	3.23	3.44	3.03	2.91	2.79	2.68	1.16	1.08	1.01	0.71	1.01	1.00	0.80	1.01
S_{60}	3.70	3.57	3.27	3.26	3.11	3.05	2.97	2.80	1.25	1.31	1.24	0.97	1.14	1.16	0.94	1.12
LSDs (0.05) P	*0.06*	*0.07*	*0.02*	*0.10*	*0.09*	*0.06*	*0.02*	*0.11*	*0.02*	*0.07*	*0.08*	*0.01*	*0.07*	*0.07*	*0.13*	*0.07*
" S	*0.06*	*0.07*	*0.02*	*0.10*	*0.09*	*0.06*	*0.02*	*0.11*	*0.02*	*0.07*	*0.08*	*0.01*	*0.07*	*0.07*	*0.13*	*0.07\ *
' P x S	*0.11*	*0.13*	*0.03*	*0.18*	*0.15*	*0.11*	*0.04*	*0.19*	*0.03*	*0.11*	*0.14*	*0.02*	*0.11*	*0.12*	*0.23*	*0.12*
	Eighth Week After Manure Application															
P_0S_0	3.67	3.49	3.41	3.29	3.82	3.43	3.30	2.91	0.90	0.89	0.87	0.77	0.88	0.85	0.87	0.81
P_0S_{30}	3.75	3.66	3.55	3.46	3.83	3.61	3.54	3.13	1.03	0.96	0.88	0.76	0.96	0.88	0.92	0.83
P_0S_{60}	3.81	3.69	3.51	3.46	3.83	3.67	3.59	3.09	1.28	1.36	1.26	1.18	1.16	1.08	1.17	1.13
Mean	**3.74**	**3.61**	**3.49**	**3.40**	**3.83**	**3.57**	**3.48**	**3.04**	**1.07**	**1.07**	**1.00**	**0.90**	**1.00**	**0.94**	**0.99**	**0.92**
$P_{30}S_0$	3.73	3.74	3.69	3.59	3.98	3.81	3.55	3.29	1.01	1.02	0.96	0.84	1.01	0.96	0.96	0.89
$P_{30}S_{30}$	3.75	3.72	3.70	3.55	3.79	3.45	3.66	3.14	1.05	1.20	1.17	0.94	1.07	1.06	1.13	1.00
$P_{30}S_{60}$	3.81	3.70	3.61	3.47	3.89	3.67	3.67	3.18	1.26	1.34	1.23	0.85	1.16	1.12	1.19	0.91
Mean	**3.76**	**3.72**	**3.67**	**3.54**	**3.89**	**3.64**	**3.63**	**3.20**	**1.11**	**1.19**	**1.12**	**0.88**	**1.08**	**1.05**	**1.09**	**0.93**
$P_{60}S_0$	3.71	3.65	3.41	3.31	3.88	3.56	3.58	3.12	0.94	0.95	0.89	0.76	0.95	0.89	0.91	0.93
$P_{60}S_{30}$	3.81	3.54	3.39	3.35	3.89	3.73	3.53	3.16	0.98	0.93	0.88	0.77	0.93	0.88	0.93	0.87
$P_{60}S_{60}$	3.87	3.66	3.46	3.33	3.89	3.53	3.71	3.22	1.07	1.11	1.01	0.93	1.09	1.01	1.04	0.93
Mean	**3.80**	**3.62**	**3.42**	**3.33**	**3.89**	**3.61**	**3.61**	**3.17**	**1.00**	**1.00**	**0.93**	**0.82**	**0.99**	**0.93**	**0.96**	**0.91**
S_0	3.70	3.63	3.50	3.40	3.89	3.60	3.48	3.11	0.95	0.95	0.91	0.79	0.95	0.90	0.91	0.88
S_{30}	3.77	3.64	3.55	3.45	3.84	3.60	3.58	3.14	1.02	1.03	0.98	0.82	0.99	0.94	0.99	0.90
S_{60}	3.83	3.68	3.53	3.42	3.87	3.62	3.66	3.16	1.20	1.27	1.17	0.99	1.14	1.07	1.13	0.99
LSDs (0.05) P	*0.00*	*0.06*	*0.06*	*0.06*	*0.04*	*0.04*	*0.09*	*0.10*	*0.08*	*0.06*	*0.09*	*0.06*	*0.06*	*0.07*	*0.06*	*0.06*
" S	*0.00*	*0.06*	*0.06*	*0.06*	*0.04*	*0.04*	*0.09*	*0.10*	*0.08*	*0.06*	*0.09*	*0.06*	*0.06*	*0.07*	*0.06*	*0.06*
' P x S	*0.00*	*0.10*	*0.11*	*0.11*	*0.08*	*0.08*	*0.16*	*0.17*	*0.13*	*0.11*	*0.15*	*0.11*	*0.10*	*0.13*	*0.10*	*0.10*

a = first location, b = second location, 1 = 0-5 cm, 2 = 5-10 cm, 3 = 10-20 cm, 4 = 20-40 cm depths, P =poultry, S = sheep and P x S = poultry and sheep manure interactions.

Table 3 Cont'd

Years and Seasons	2019 a				2019 b				2020 a				2020 b			
Soil Depths	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Manure Rates	Twelfth Week After Manure Application															
P_0S_0	3.51	3.50	3.50	3.56	3.19	3.16	3.12	3.15	0.88	0.86	0.96	0.78	0.77	0.75	0.84	0.69
P_0S_{30}	3.71	3.70	3.84	3.75	3.60	3.43	3.30	3.29	1.03	1.03	0.99	0.85	0.83	0.86	0.86	0.82
P_0S_{60}	3.63	3.64	3.82	3.81	3.54	3.48	3.36	3.29	1.37	1.33	1.34	1.02	1.17	1.13	1.14	0.88
Mean	**3.62**	**3.61**	**3.72**	**3.71**	**3.44**	**3.36**	**3.26**	**3.24**	**1.09**	**1.07**	**1.10**	**0.88**	**0.92**	**0.91**	**0.95**	**0.80**
$P_{30}S_0$	3.64	3.76	3.60	3.67	3.41	3.32	3.23	3.19	1.05	1.10	1.10	0.82	0.88	0.90	0.90	0.75
$P_{30}S_{30}$	3.73	3.59	3.69	3.69	3.42	3.33	3.28	3.32	1.11	1.18	1.15	0.95	0.85	0.91	0.95	0.81
$P_{30}S_{60}$	3.80	3.72	3.53	3.73	3.37	3.31	3.21	3.19	1.44	1.34	1.39	0.98	1.22	1.14	1.19	0.91
Mean	**3.72**	**3.69**	**3.61**	**3.70**	**3.40**	**3.32**	**3.24**	**3.23**	**1.20**	**1.21**	**1.21**	**0.92**	**0.98**	**0.98**	**1.01**	**0.82**
$P_{60}S_0$	3.80	3.60	3.71	3.87	3.32	3.21	3.26	3.24	0.88	0.97	0.96	0.88	0.78	0.84	0.82	0.81
$P_{60}S_{30}$	3.55	3.66	3.59	3.81	3.51	3.42	3.29	3.14	0.89	0.95	0.98	0.83	0.86	0.88	0.88	0.79
$P_{60}S_{60}$	3.70	3.62	3.77	3.61	3.53	3.47	3.39	3.39	1.08	1.12	1.17	0.96	0.88	0.88	0.90	0.83
Mean	**3.68**	**3.63**	**3.69**	**3.76**	**3.45**	**3.37**	**3.31**	**3.26**	**0.95**	**1.01**	**1.04**	**0.89**	**0.84**	**0.87**	**0.87**	**0.81**
S_0	3.65	3.62	3.60	3.70	3.31	3.23	3.20	3.19	0.94	0.98	1.01	0.83	0.81	0.83	0.85	0.75
S_{30}	3.66	3.65	3.71	3.75	3.51	3.39	3.29	3.25	1.01	1.05	1.04	0.88	0.85	0.88	0.90	0.81
S_{60}	3.71	3.66	3.71	3.72	3.48	3.42	3.32	3.29	1.30	1.26	1.30	0.99	1.09	1.05	1.08	0.87
LSDs (0.05) P	*0.04*	*0.06*	*0.02*	*0.09*	*0.07*	*0.04*	*0.05*	*0.02*	*0.06*	*0.05*	*0.05*	*0.07*	*0.06*	*0.09*	*0.08*	*0.06*
" S	*0.04*	*0.06*	*0.02*	*0.09*	*0.07*	*0.04*	*0.05*	*0.02*	*0.06*	*0.05*	*0.05*	*0.07*	*0.06*	*0.09*	*0.08*	*0.06*
' P x S	*0.07*	*0.11*	*0.03*	*0.17*	*0.12*	*0.07*	*0.08*	*0.03*	*0.11*	*0.09*	*0.09*	*0.12*	*0.11*	*0.14*	*0.14*	*0.10*

a = first location, b = second location, 1 = 0-5 cm, 2 = 5-10 cm, 3 = 10-20 cm, 4 = 20-40 cm depths, P =poultry, S = sheep and P x S = poultry and sheep manure interactions.

4.0 Conclusions

This work investigates nitrogen mobility in degraded Ultisols following the application of poultry and sheep manures, addressing an important issue in tropical soil fertility and sustainable agriculture. The study examined multiple depths, locations, and sampling periods in tropical soils. However, the results confirm that manure application increased soil nitrogen and that nitrogen concentration decreased with depth till 20 cm depth, which aligns with expectations of root uptake by plants.

The results confirm that manure application increased soil nitrogen and that nitrogen concentration decreased with depth, which aligns with expectations of plant uptakes and leaching of nutrients. The poultry, sheep and integration of the two manures incorporated increased soil total N concentrations with integration ($P_{60}S_{30}$) increased than the single doses in the first and second locations in 2019 and 2020. Soil total N decreased as the depth increased but inconsistent in some weeks and locations. During second locations, it decreased relative to the first locations in both years. The highest values were obtained at about eighth week at all depths relative to other weeks in the second location in 2019 while at 0 – 10 cm soil depths during first and third weeks in first location of 2020.

Acknowledgements

We would like to extend our utmost appreciation to the reviewers, editor(s), and people who provided their time and insight in making this research a better document. Meanwhile, the expressions, views, and conclusions generated are for the authors.

Funding Declaration
There was no funding during this experiment.

Competing Interest Declaration
There was no competing interest.

References

Abdelrazzak, A. (2002). Effect of Chicken Manure, Sheep Manure and Inorganic Fertilizer on Yield and Nutrients Uptake by Onion. *Pak J Biol Sci.*, 5: 266 - 268.
http://dx.doi.org/10.3923/pjbs.2002.266.268

Adaikwu, A. O., Ali, A. (2013). Assessment of some soil quality indicators in Benue State. *Nig J Soil Sci.* 23(2): 66 - 75.

Agbede, T. M. (2025). Poultry manure improves soil properties and grain mineral composition, maize productivity and economic profitability. Nature Portfolio. Scientific Report, 15(1), DOI:10.1038/s41598-025-00394-8

Aro, O. A., Agwu, J. A. (2005). Effect of animal manure on selected soil chemical properties. *J Soil Sci.*, 15: 14 - 19.

Atasoy, M. and Cetecioglu, Z. (2022). The effects of pH on the production of volatile fatty acids and microbial dynamics in long-term reactor operation. *Journal of Environmental Management,* 319(1), 115700. https://doi.org/10.1016/j.jenvman.2022.1157

Atoma, C. N., Mathews-Njoku, E. C., Nnadi, F. N. (2015). Analysis of rural household use of organic farming-practices-amongst livestock farmers in South-South Nigeria. Achieving social and economic development through ecological and organic agricultural alternatives. The 3rd African Organic Conference Nigeria, Pp 155 – 158.

Awodun, A. (2007). Effect of Poultry Manure on the Growth, Yield and Nutrient Content of Fluted Pumpkin (*Telfaria occidentalis* HookF). *Asian J Agric Res.* 1: 67 - 73.

Ayed, A. (2002). Effect of chicken manure, sheep manure and inorganic fertilizer on yield and nutrients uptake by onion. Science Alert. DOI:10.3923/pjbs.2002.266.268. http://scialert.net/abstract/?doi=pjbs.2002.266.268. Pp 1 – 4.

Azeez, J. O., Van Averbeke, W. (2010). Nitrogen mineralization potential of three animal manures applied on a sandy clay loam soil. *Biores Tech*. 101. 5645 - 5651.

Brader, I. A. (2011). Long – term trends in fertility of soils under continuous cereal cultivation. *Int J Pure Applied Sci..* 40 : 203 – 209.

Cam, W. F. (2009). Effects of poultry manure on soil physico – chemical properties and maize yield in Southeastern Nigeria. *Soil Fert Res*. 26 (26): 321 – 326.

Chukwuka, C. (2013). Rice – Effect of organic and inorganic fertilizer on the growth yield of three lowland Rice varieties. doubleGist.CO. Pp. 1– 13.

Clemens, D. F, Whitehurst, G. B. (1990). *Chelates in Agric Fertr Res.* 25: 127 - 131.

Cooke, B. (2001). Updates of Development in Nigeria Organic Agriculture. A Review and possible adoption for food security. Pp. 11.

Dipeolu, A. O., Akinbode, S. O. (2005). Consumer perceptions of organic produce in Abeokuta.
In "Proceeding First National Conference on Organic Agriculture UNAAB, Abeokuta.
25 – 28th October" Olasantan *et al* (ed). Pp. 191 – 196.

Enwezor, W. O., Ochiri, A. C., Opuwaribo, E. E., Udoh, J. E. (1990). A review of soil fertility Investigation in Nigeria, FMAMR, Lagos 6.

Evanylo, G. K. (1997). Effects of organic and chemical inputs on soil quality. Virginia Cooperative Extension. Crop and Soil Environmental News. http://www.sites.ext.vt.edu/newsletter-archive/cses/1997-12/1997-12-03.html. Pp 1 – 3.

Fathi, A. (2022). Role of nitrogen (N) in plant growth, photosynthesis pigments, and N use efficiency: A review. *Agrisost*, 28, 1 – 8, https://doi.org/10.5281/zenodo.7143588

Gamage, A., Gangahagedara, R., Gamage, J., Jayasinghe, N., Kodikara, N., Suraweera, P. and Merah, O. (2023). Role of organic farming for achieving sustainability in agriculture. *Farming System* 1(1). https://doi.org/10.1016/j.farsys.2023.100005

Gee, G. W., Or D. (2002). Particle size analysis. In: Dane, JH & Topps, GC (eds). Methods of Soil analysis, Part 4. Physical methods. Soil Science Society of America Book Series NO. 5, ASA & SSSA, Madison, WI. Pp 255 – 293.

Genstat (2012). Reference manual (Genstat Release 7.0) VSN International Limited, Oxford, UK. www.discovery.genstat.co.uk.

Guoce, X. U., Shengdong, C., Pang, U., Zhanbin, U., Haidong, Kunda, Y. U., Shi, P., Chang, Y., Zhao, B. (2018). Soil total nitrogen sources on dammed farmland under the condition of ecological construction in a small watershed on the loess Plateau, China. *Ecol Eng.*, 121: 19 – 25.

Hargreaves, J. C., Adi, M. S., Warman, P. R. (2008). A review of the use of composted municipal solid waste in agriculture. *Agric, Ecosys Environ*. 123(1 – 3): 1 – 14. https://doi.org/10.1016/j.agee.2007.07.004

Harishma, H., Kalaimegam, A., Pandi, A. and Tharani, K. M. (2025). Soil fertility and nutrient management. In book: Principles and Practices in Agronomy: Innovations for Sustainable Crop Production Pp.1 – 23.

Hassan, A., Bashir, H., Rehman, R. S. and Zafar, S. (2023). The importance of soil organic matter (SOM) on soil productivity and plant growth. *Biological and Agricultural Sciences Research Journal*, 2(11): 1 - 9. DOI:https://doi.org/10.54112/basrj.v2023i1.11

Havlin, J. L., Beaton, J. D., Tisdale, S. L., Nelson, W. L. (1999). Soil Fertility and Fertilizers, 6th Edition. Upper Saddle. River, New Jersey: Prentice - Hall, Inc. Pp. 499.

Hill (2001). Soil Tests and Interpretation. Technical Notes. Hill laboratories, www.hill - laboratories.com. 4, 3196. Pp. 1 - 9.

Ibrahim, U., Abdul Rahman, S. (2015). Optimum returns in irrigated groundnut as influenced by poultry manure rates at Kadawa in the Sudan Savanna Ecological Zone of Nigeria. Scientific Track Proceedings of the 3rd African Organic Conference. Achieving Social and Economic Development through Ecological and Organic Agricultural Alternatives, Lagos, Nigeria. Pp 15 – 19.

IFPRI (2005). Food Consumption and Nutrition. International Food Policy Research Institute. Pp. 30 – 41.

Ikeh, A. O., Ndaeyo, N., Uduak, I., Iwo, G., Ugbe, L., Udoh, E. I., Effiong, G. S. (2012). Growth and yield responses of pepper (Capsicum Frutescens L.) to varied poultry manure rates in Uyo, Southeastern Nigeria. ARPN J. *Agric. Biol. Sci*. 7(9).

Imadi SR, Shazadi K, Gol A, Hakeem KR (2015) Sustainable Crop Production System In book: Plant Soil and Microbes, Vol. 1st, Impications in Crop Science, Edition: 2016, DOI:10.1007/978-3-319-27455-3_6.

IPEDC (2006). Imo State of Nigeria Statistical Year Book. Published by Imo State Planning and Economic Development Commision, State Secretariat, Port Harcourt Road, Pp 282.

Iren, O. B., John, N. M., Imuk, E. A. (2014). Effects of sole and combined applications of organic manures and urea on soil properties and yield of fluted pumpkin (*Telfaria occidentalis*, Hook F.). *Nig J Soil Sci.*, 24(1): 125 – 133.

Jackson, M. L. (1973). Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd., New Delhi, 498.

James, W. (2013). Nitrogen in soil and the environment. Cooperative Extension. University of Arizona. Az1591. Pp. 1 – 3.

Keller, M. (2005). Nitrogen – Friend or Foe of Wine Quality. *Practical Winery and Vineyard Journal*. Washington State University. Pp 2054.

Khan, M. T., Aleinikoviené, J. and Butkeviciené, L. M. (2024). Innovative Organic Fertilizers and Cover Crops: Perspectives for Sustainable Agriculture in the Era of Climate Change and Organic Agriculture. *Agronomy* 2024, *14*(12), 2871; https://doi.org/10.3390/agronomy 14122871

Kumar, S., Sharma, A., Rahul and Rahul (2023). Effect of Organic Manures on Growth, Yield and Quality of Vegetable Crops — A Review. Frontiers in Crop Improvement. Vol 11 : 1633-1638 (Spe cial Is sue-III) July 2023, Print ISSN : 2393-8234 On line ISSN : 2454 – 6011.

LAS (2014). Soluble Salts or Electrical Conductivity of Soils and Green house Media. Litchfield Analytical Services. Pp. 1 – 2.

Lewandowski, A. (2017). Manure management. Soil management and health. University of Minnesota Extension. Pp 1 – 10.

Li, J. T., Zhong, X. L., Wang. F., Zhao, Q. G. (2018). Effect of poultry litter and livestock manure on soil physical and biological indicators in a rice-wheat rotation system. *Plt, Soil Environ.*, 57(8): 351 – 356.

Liu, X., Xu, Y., Jia, H., Zhao, Y., Hou, H. and Zhang, Y. (2025). NH_3 release during the evaporation of different types of atmospheric precipitation: A case study in Changchun, China. Scientific Reports 15(31117); 2025.

Lu, R., Liang, R. and Duan, W. (2021). Dispersion and stability of fine-grained soils under different pretreatments based on the particle size distribution. *Journal of soils and sediments*, 21: 96 – 105.

Maynard, L. (2015). Nitrogen loss from wet soils. Purdue University. https://vegcropshotline/article/nitrogen-loss-from-wet-soils/

McCauley, A., Clain, J., Jeff, J. (2009). Soil pH and organic matter. Nutrient management module No 8. Montana State University Extension Continuing Education Series. Pp. 4447 – 4448.

Mhlontlo, S., Muchaonyerwa, P., Mnkeni, P. N. S. (2006). Effects of sheep kraal manure on growth, dry matter yield and leaf nutrient composition of a local *Amaranthus* accession in central region of the Eastern Cape Province, South Africa. International Symposium on the National Value and Water Use of Indigenous Crops for Improved Livelihoods. University of Pretoria, Pretoria, South Africa. (special edition) 2007. 33, 3: 363 – 368. Retrieved from http://www.wrc.org.za.

Mulvaney, R. L. (1996). Nitrogen- Inorganic forms. Cover crops and soil ecosystem services. Methods of Soil Analysis: Part 3 Chemical methods, 5.3, Book Series, Chapter 38. https://doi.org/10.2136/sssabookser

Mysen, B. (2019). Nitrogen in the Earth: abundance and transport. Progress in Earth and Planetary Science 6(1). DOI:10.1186/s40645-019-0286-x

Neenu, S., Karthika, K. S. (2019). Aluminium toxicity in soil and plants. *Harit Dhara*. 2(1): 15 – 19.

Nelson, D., Sommers, L. E. (1996). Total carbon, organic carbon and organic matter. In: Sparks DL (ed): methods of soil analysis. ASA. SSSA.Madison, Wisconsin, USA. Pp 961 – 1010.

NRCS-USDA (2022). Soil Health – pH. Natural Resources Conservation Services – United States Department of Agriculture. pH - Soil Health Guide_0.pdf

Nwajiuba, C., Akinsanmi, A. (2002). Organic Manure Use among Smallholders in the Rainforest of Southeast Nigeria. University of Hohenheim, Department of Agricultural Economics and Social Sciences in the Tropics and Subtropics, Fruwirthstrabe 12, 70593.

Obiefuna, J. C., Ibeawuchi, I. I., Ekong, E. A., Okoli, N. A., Alagba, R. A. (2012). Liming efficiency of arsenite in rice and their role in Arsenic accumulation in rice grain. Proceedings of the National Academy of Sciences, USA 105: 9931–9935.

Omokaro, G. O., Osarhiemen, I. O., Idama, V. and Airueghian, E. (2024). The Role of Organic Amendments and Their Impact on Soil Restoration: A Review**.** *Asian Journal of Environment & Ecology* 23(11):41-52. DOI:10.9734/ajee/2024/v23i11620

Ononogbo, C., Ohwofadjeke, P. O., Chukwu, M. M. and Nwawuike, N. (2024). Agricultural and

environmental sustainability in nigeria: a review of challenges and possible eco-friendly

remedies. *Environmental Development and Sustainability*.

DOI:10.1007/s10668-024-05435-2

Osama, H. M., Amro, E. G., Salama, S. M. (2016). Effect of sheep manure application rate and method on growth, fruiting and fruit quality of Balady guava trees grown under mid-Sinai conditions. Doi: 10.9790/2380-09115972, Pp 58 – 72.

Pam, H., Brian, M. (2007). Interpreting Soil Test Results. What Do All the Numbers Mean? Pam Hazelton and NSW Department of Natural Resources. Pp. 1 – 66.

Porter, D. O. (2004). Utilization of organic wastes. On farm Composting fact sheet series 2004 http.//cwmiocsscornelledu/composting.html. *An int J Agric Sci., Sci, Environ Technol.*. 7,1(2007).

Prasad, R., Chakraborty, D. (2019). Phosphorus Basics Understanding Phosphorus Forms and Their Cycling in the Soil. Soil production. Extension. Alabama Universities.

Richards, L. A. (ED) (1954). Diagnosis and Improvement of Saline and Alkali Soils. United State Department of Agriculture Handbook. Pp. 60.

Saidia, P. S. (2023). The Impact of Biochar and Animal Manure on Soil Properties, Yield, and Quality of Crops. In book: Manure Technology and Sustainable Development, pp.183 – 196. DOI:10.1007/978-981-19-4120-7_7

Saka, H. A., Azeez, J. O., Odedina, J. N. and Akinsete, S. J. (2017). Dynamics of soil nitrogen availability indices in a sandy clay loam soil amended with animal manures. *Int J Recycl Org Waste Agricul*. 6: 167 – 178. DOI 10.1007/s40093-017-0165-7.

Saka H. A., Uzoho B. U., Ahukaemere C. M. and Nkwopara U. N. (2023[a]). Dynamics of Nitrate - Nitrogen of Poultry and Sheep Manures Amended Degraded Ultisols in Ihiagwa, Southeastern Nigeria. *International Journal of Research and Scientific Innovation*, 10(8): 59 – 72, **DOI:** https://doi.org/10.51244/IJRSI.2023.10806

Saka, H. A., Uzoho, B. U., Ahukaemere, C. M. and Nkwopara, U. N. (2023[b]). Migration of soil ammonium- nitrogen with amended poultry and sheep manures in Ultisols of Ihiagwa, Southeastern Nigeria. *International Journal of Research and Scientific Innovation*, 10(7): 155 – 167, DOI:10.51244/IJRSI

Scotti, R., Bonanomi, G., Scelza, R., Zonia, A. and Rao, M. A. (2015). Organic amendments as sustainable tool to recovery fertility in intensive agricultural systems. *J Soil Sci Plt Nutri*, 15, 333 – 352. https://doi.org/10.4067/18-95162015005000031

Sharma, A. R. and Mittra, B. N. (1991). Effect of Different Rates of Application of Organic and Nitrogen Fertilizers in a Rice-Based Cropping System. *The J Agric Sci.,* 117, 313 - 318. https://doi.org/10.1017/S0021859600067046

Sharma, Po., Sharma, Pa. and Tharkur, N. (2024). Sustainable farming practices and soil health: a pathway to achieving SDGs and future prospects, vol. 5. Sustainable farming practices and soil health: a pathway to achieving SDGs and future prospects | Discover Sustainability | Springer Nature Link

Shi, Y., Eissenstat, D. M., He, Y., Davis, K. J. (2017). Using a spatially-distributed hydrologic biogeochemistry model with nitrogen transport to study the spatial variation of carbon stocks and Fluxes in a Critical Zone Observatory. American Geophysical Union Fall Meeting, New Orleans, LA.

Singh, A. K. (2021). Organic manures. Project e-content development. Soil Survey Staff (1999). Soil Taxonomy: a basic system of soil classification for making and interpreting soil surveys. USDA Agric. Handbook, No. 456, 2nd edition. U. S. Govt. printing office, Washington D. C. Pp 868.

Soremi, A. O., Adetunji, M. T., Adejuyigbe, C. O., Bodunde, J. G., Azeez, J. O. (2017). Effects of Poultry manure on some soil chemical properties and nutrient bioavailability to soybean. *JAERI,* 11(3): 1 – 10.

Sylvia, D. M., Furmann, J. J., Hartel, P. G., Zubere, D. A. (eds) (2004). Principles and Applications of Soil microbiology, Second Edition. Prentice Hall, Upper Saddle River, New Jersey.

Tadewos, T., Ayalew, T., Yoseph, T. (2022). Effect of biological and chemical fertilizers Combination on yield of mung bean (*Vigna radiate* L.Wilezek) at Hawassa Southern Ethiopia. *J Plt Sci.*. 10(4): 97 – 104.

Terry, S. L. (2002). Sustainability; prospect and future. *Sust Agric.*, 6 (4): 17 - 42.

Tiwari, A. K. (2023). The Role of Organic Farming in Achieving Agricultural Sustainability: Environmental and Socio-economic Impacts. *Acta Biology Forum* 2(2): 29 – 32. **DOI:**10.51470/ABF.2023.2.2.29

Tom, D. (2002). Nitrogen Sources. University of Nebraska Lincoln Extensoin. 402. 441 – 7180/http://Lancaster.uni.edu. Pp. 288.

Umass (2017). Plant nutrients from manure. Crops, dairy, livestock and equine program Agriculture, food and the environment. Pp 1 – 4.

UNCTAD (2008). Organic agriculture and food security in Africa. United Nations Conference on Trade and Development. United Nations Environment Programme (UNEP)-UNCTAD Capacity-building Task Force on Trade, Environment and Development.UN, New York and Geneva, Pp 47.

Usman M. (2015). Cow dung, goat and poultry manure and their effects on the average yields and growth parameters of tomato crop. *J Biol, Agric Healthcare*. Pp 1 – 3.

Uzoho, B. U. (2010). Field and Laboratory Evaluation of dynamics in soil properties of selected land-use types in Owerri, Southeastern, Nigeria. *Inter. Journ. Agric & Rural Dev*. 13(2): 268 - 273.

Uzoho, B. U., Ahukaemere, C. M., Egboka, N. T., Afangide, I. A., Okoli, H. N., Irokwe, I. F.,

Ubakwe, R. C. (2022). Potassium quantity intensity concepts of soils of contrasting landscape positions in the humid rain forest, Southeastern Nigeria. *Adv J Sci, Eng. Technol.*, 7(10): 1 – 21.

Uzoho, B. U., Ihem, E. E., Ogueri, E. I., Igwe, C. A., Effiong, J. A., Njoku, G. U. (2016). Potassium Forms in Particle Size Fractions of Soils on Toposequence in Mbano, Southeastern Nigeria. *Int J Environ Poll Res*, 1 – 11.

Van Averbeke, W., De Lange, A. O. (1995). Agroecological conditions and land use. In: De Wet, C. and Van Averbeke, W.. (eds.). Regional Overview of Land Reform – Related Issues in the Eastern Cape Province. Working paper 24 EC 2, LAPC, Johannesburg. Pp 62.

Van Averbeke, W., Yoganathan, S. (1997). Using kraal manure as a fertilizer. ARDRI, FortHare and the National Department of Agriculture, Resources Centre, Directorate Communication. Government Printer, Pretoria, South Africa. Pp 19.

Verma, S., Pradhan, S. S., Singh, A. and Kushuwaha, M. (2024). Effect of Organic Manure on Different Soil Properties: A Review. *International Journal of Plant & Soil Science*, 36(5): 182 – 187. **DOI:** 10.9734/ijpss/2024/v36i54515

Watts, D., Horvath, T., Tobert, H. A. and Adesemoye, A. O. (2023). Effects of Selected Manure Sources on Runoff, Soil Loss, and Nutrient Transport. *Applied Engineering in Agriculture*. **DOI:**10.13031/aea.15651

White, P. J., Crawford, J. W., Álvarez, M. C. D., Moreno, R. G. (2012). Soil management for sustainable agriculture. https://doi.org/10.1155/2012/850739.

Willer, H., Kilcher, L. (eds) (2011). The world of organic agriculture: statistics and emerging trends 2011. International Federation of Organic Agriculture Movements, Bonn & Research Institute of Organic Agriculture, Frick, Switzerland. Available at: www.organic-world.net/yearbook-2011-contents.html.

Yagoub, S. O. (2012). Effect of urea, NPK and compost on growth and yield of soybean (*Glycine max* L.), semi-arid region of Sudan. *International Scholarly Research Notices*. https://doi.org/10.5402/2012/678124.

Zhao, C. B., Liu, S., Piao, X., Wang, D. B., Lobell, Y., Huang, M., Huang, Y., Yao, S., Bassu, P., Ciais, J-L., Durand, J., Elliott, F., Ewert, I. A., Janssens, T., Li, E., Lin, Q., Liu, P., Martre, C., Müller, S., Peng, J., Peñuelas, A. C., Ruane, D., Wallach, T., Wang, D., Wu,

Z., Liu, Y., Zhu, Z., Zhu, S., Asseng (2017). Temperature increase reduces global yields of major crops in four independent estimates. *Proc. Natl.Acad. Sci.*, 114(35): 9326 – 9331, doi:10.1073/pnas.1701762114.