ISSN 2756-4444
E-ISSN 2756-4452

SOIL QUALITY ASSESSMENT FOR SUSTAINABLE LAND MANAGEMENT IN SELECTED LOCATIONS IN MALETE, MORO LOCAL GOVERNMENT AREA, KWARA STATE

BY

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Abstract

Soil quality can be assessed by measuring soil properties, otherwise known as soil indicators. This study assessed soil quality in selected sites at Malete, Moro Local Government area of Kwara state, by evaluating its physical and chemical properties. Soil samples were collected from farmland and forestland sites in Malete, Kwara State. Physical and chemical properties, including pH, nitrogen, potassium, sodium, magnesium, phosphorus, organic carbon, organic matter, water holding capacity, cation exchange capacity, soil porosity, and bulk density, were determined using standard procedures and methodologies. A t-test was used to analyze significant differences ($p<0.05$) between the two locations. The results showed that forestland soils had a neutral pH (7.09), while farmland soils were slightly acidic (pH 6.93). Farmland had higher nitrogen (0.27%), potassium (1.22 mg/kg), and sodium (0.26 mg/kg) compared to forestland soils, although these differences were not significant. Forestland soils had significantly higher magnesium (2.14 mg/kg), available phosphorus (29.52 mg/kg), and cation exchange capacity (5.78). Farmland soils exhibited significantly higher total organic carbon (2.70 mg/kg), organic matter (4.66 mg/kg), and water-holding capacity. Forestland soils had higher porosity (68.15%) and bulk density (2.52 g/cm³) than farmland. The results highlight key differences in soil properties between forestland and farmland. Forestland soil is generally healthier than farmland soil, with better pH, magnesium, phosphorus, and Cation Exchange Capacity, which promote fertility and plant growth. However, farmland soil shows higher nitrogen, potassium, and sodium levels, beneficial for short-term crop productivity.

Keywords: **soil quality, soil health, forestland, farmland, Local Government**

Introduction

Soil quality is a key component of sustainable land management which directly impacts land use, agricultural production, and environmental health (Lobmaan*et al*., 2022). Creating sustainable land management (SLM) strategies that work requires an accurate assessment of soil quality, especially in areas with a variety of land uses (van der Laan *et al*., 2023). Unsustainable agricultural methods and land degradation have prompted worries about the health of the soil and long-term land production in various parts of Nigeria including Malete, in Moro Local Government Area of Kwara State, Nigeria (Auwalu*et al*., 2022). Tahat*et al*. (2020) focused on how keeping healthy soil is essential for long-term agricultural sustainability and how soil deterioration lowers production and ecosystem services. In this regard, markers of soil quality, including pH, organic matter content, availability of nutrients, and soil structure, are crucial for assessing soil health and directing sustainable management techniques. The use of soil quality tests in different parts of Nigeria to promote sustainable agriculture has been the subject of recent research. For example, a thorough evaluation of soil fertility in Kwara State, Nigeria, byTajudeen*et al*. (2017) revealed notable differences in soil quality among various land use types. Their results highlight the necessity of site-specific management strategies to improve crop performance and solve problems with soil fertility. Kianguebene-Koussingounina*et al*. (2022) also investigated soil quality evaluation in Ibadan southwest Nigeria, identifying environmental elements and land use practices as major determinants of soil health. Their study emphasizes how crucial it is to incorporate studies of soil quality into land management plans to slow down land degradation and advance sustainable agriculture.

Although a great deal of study has been done on the evaluation of soil quality in different parts of Nigeria, there is a notable lack of information in the literature about in-depth studies that are location-specific in Malete, Moro Local Government Area, Kwara State. Previous research, such as that done by Tajudeen*et al*. (2017) has concentrated on more general evaluations of soil fertility in Irepodun Local Government of Kwara State rather than offering thorough assessments that are specific to the particular environmental circumstances and land use patterns in Malete. In a similar vein, research by Kianguebene-Koussingounina*et al*. (2022)has emphasized the significance of soil quality assessments in Ibadan southwest Nigeria, but it does not address the unique difficulties that soils in the Malete area, where land use changes and agricultural growth are happening quickly, face. Due to variations in land use, geography, and management techniques, soil parameters can change dramatically over short distances, making this gap in location-specific data crucial. The absence of comprehensive evaluations of Malete's soil quality hinders the development of focused sustainable land management (SLM) plans, which are essential for preserving the region's agricultural output and soil health. Research on soil quality in Malete will provide the required information to direct efficient SLM procedures and encouragelong-term environmental sustainability of the area. This study assessed the quality of the soil at some selected Malete sites to improve land degradation mitigation, sustainably manage land, and encourage sustainable agricultural development in the area.

Materials and Methods

Study site selection

The study was conducted in Malete, Moro Local Government Area, Kwara State, located at 4° 28' 0" E longitude and 8° 41' 59" N latitude. The area experiences two seasons: rainy and dry, with temperatures ranging from 22°C to 33°C, an average of 28°C, 51.6 mm of precipitation, and 60% annual humidity (Weather by CustomWeather, © 2024). Forestland and farmland were selected for the study. Crops like corn, yams, peppers, tomatoes, and vegetables have been continuously cultivated for five years on the farmland. The forestland remains relatively undisturbed. Four transects were established at the cardinal points (west, east, south, and north) with eight representative profiles selected—two in each direction (Abua and Ajake, 2013).

Soil sample collection and preparation

Soil samples were collected with a soil auger, at a depth of 0–20 cm, air-dried for seven days, crushed to separate larger debris, and sieved through a 2mm sieve. The processed samples were then packed, labeled, and prepared for various analyses, including pH, total nitrogen, available phosphorus, organic carbon, cation exchange capacity, and other physical and chemical properties.

Determination of Physicochemical parameters

The soil pH was determined using a glass electrode pH meter (Kalra*et al*., 1995). Determination of nitrogen was done according to the procedure of Bremner, 1960 using the Micro Kjeldahl Method. Soil of 2g was weighed into a Kjeldahl flask, 0.5g of $CuSO_4 \cdot 7H_2O$, and 10g of Na_2SO_4 were added. Then, 25cm³ of concentrated sulphuric acid was poured in. The flask was heated gently for 15 minutes, then vigorously for 45 minutes, until the mixture turned a brilliant green. After cooling, the digested sample was transferred to a 250ml volumetric flask and diluted with distilled water. For distillation, 5 ml of the digested sample was mixed with 5 ml of 40% NaOH. Ammonia was released and collected into 2% boric acid, turning the indicator from blue to green. Another 2g of air-dried sample was weighed into a 250ml conical flask for the determination of organic matter, and total carbon using the Walkey Black Wet Oxidation Method (1947). About 10 ml of potassium dichromate solution was added, swirled, and then

ISSN 2756-4444
E-ISSN 2756-4452

sulphuric acid was rapidly mixed in. After 30 minutes, 100ml of distilled water and 3 drops of ferroin indicator were added. The solution was titrated with iron sulphate until the color changed from green to maroon. Organic matter, and total carbon were calculated, and sodium and potassium were determined using a flame photometer. Soil particle size was determined according to the method described by Bouyoucos, 1927. About 50g of air-dried, sieved soil sample was weighed into a 250 ml conical flask, and 4 ml of 40% NaOH was added. After adding 50ml of water, the mixtures were stirred for 2-5 minutes using a magnetic stirrer. The mixture was transferred to a 1-liter measuring cylinder, and a soil hydrometer was inserted, and then removed after agitation. Hydrometer readings and temperatures were recorded at 40 seconds and again after 2 hours. The following calculations were further adopted: Calculations**:**

$$\% \text{ silt} + \text{clay} = \frac{\text{40sec corrected hydrometer reading}}{\text{weight of sample}} \times 100$$

$$\% \text{ clay} = \frac{\text{2hrs corrected hydrometer reading}}{\text{weight of sample}} \times 100$$

% sand =100 – (% silt + percentage clay).

In addition, water holding capacity was determined according to the method described by Herawati*et al.* (2021). Upon arrival at the laboratory, soil samples were air-dried to a consistent moisture content to establish a baseline for water-holding capacity measurements. The dried samples were sieved for uniformity, and a known quantity was measured into a 250 ml conical flask. Water was added gradually and the mixture was allowed to equilibrate before draining excess water. The soil's weight after saturation represented its water-holding capacity, expressed as a percentage of the soil mass, indicating the maximum water retention against gravity. Mw = Mt – Ms. Where Mw is the mass of water in grams, Mt is the total mass of the container and wet soil in grams, Ms is the total mass of the container and dry soil in grams. It is worth noting that the mass of water in grams is equivalent to its volume in milliliters. Thus, Vw = Mw. Therefore, the percentage of Water Holding Capacity (WHC%) = (Vw/Vt) * 100, where Vw is the volume of water, and Vt is the total volume of saturated soil. Available phosphorous was determined by the method of Bray et al. (1957) with little modifications. About 5g of air-dried soil samples were weighed into sample bottles. 35ml of extracting solution (1N ammonium fluoride and 0.5ml hydrogen chloride) was added, and the mixtures were shaken for 5 minutesand then filtered using the Whatman No. 42 filter paper. 5ml of the extract was pipetted, and 5ml of development solution was added. The contents were made up to 50 in a volumetric flask with distilled water and left for 30 minutes. Absorbance was measured at 660nm using a spectrophotometer, and the procedure was repeated for a blank without soil. Other physical and chemical parameters were analyzed with standard procedures and methodologies

Statistical Analysis

The differences in soil physicochemical properties by habitat were examined by providing summary statistics between the habitats and presented in graphs using the ggplot function in R. A t-test was conducted to ascertain if these differences were significant at $p<0.05$. All statistical analyses and graphing were performed in R version 4.3.0.

Results and Discussions

Physical and chemical properties of the soil

Soil pH

The differences in the physical and chemical properties between the two locations (farmland and forest) are presented in Figures 1 to 5 while Table 1 further shows the t-test results and the p-values for the data obtained during the research. A highly significant (p<0.05) pH value of 7.09 was observed in forestland (Table 1), indicating neutral soils compared to farmland with a pH value of 6.93 indicating slightly acidic soils. Similar results were reported by Jugulde*et al*. (2020) during the assessment of soil fertility status in Bali Local Government, Taraba State Nigeria. Meanwhile, Ojha and Chaudhary (2017) observed different results with their research on soil quality assessment posed by industrial effluents in BansbariIndustrial Area of Morang District, Nepal, India where an alkaline pH range of 7.75 - 8.32 was observed. Given that macronutrients like potassium, phosphorus, and nitrogen are more soluble at neutral pH levels, neutral soils in the forest may promote more nutrient availability (Jackson and Meetei, 2018). Conversely, the somewhat acidic soils found in farmland may restrict the availability of certain nutrients, particularly phosphorus, which could impact plant development and yield (Yadaf*et al*., 2020). The soil's pH significantly influences the microbial community's structure and activity. The microbial community in forest soils is probably more varied and active when the pH is neutral, which willpromote nutrient cycling and the breakdown of soil organic matter. Microbial diversity may be decreased in farmed soils that are somewhat acidic, which could slow down these processes and affect soil fertility. Neutral pH in forest soils is frequently linked to increased levels of organic carbon, which increases carbon sequestration. This may have important implications for mitigating climate change (Sun *et al*., 2023). However, agricultural soils of slightly acidic pH may lessen their ability to retain carbon, particularly if agricultural practices do not encourage the preservation of soil organic matter (Cortijos-López*et al*., 2023).

Table 1: Physical and Chemical properties of Soils in Farmland and Forest

Variable	t-statistic	Farmland	Forest	*p* value
pH	− 2.50	6.93	7.09	0.03*
Total Nitrogen (%)	1.53	0.27	0.19	0.16
Titratable Acidity	−0.18	0.23	0.24	0.86
Available P (mg/kg)	−1.54	19.94	29.52	0.16
Total Organic Carbon (%)	2.19	2.70	2.15	0.04*
Organic Matter (%)	2.19	4.66	3.72	0.04*
Potassium (mg/kg)	1.01	1.22	1.15	0.32
Sodium (mg/kg)	1.78	0.26	0.22	0.09
Calcium (mg/kg)	−8.96	1.31	2.042	< 0.001*
Magnesium (mg/kg)	−0.69	1.98	2.14	0.50
CEC (cmol/kg)	−2.58	5.01	5.78	0.02*
ECEC(cmol/kg)	0.07	4.78	4.75	0.95
Bulk Density(g/cm^3)	−2.36	2.43	2.52	0.03*
Electrical Conductivity	−1.03	22.99	24.73	0.32
Water Holding Capacity	3.56	2.06	1.95	0.002*
Moisture Content	1.47	9.73	8.45	0.17
Soil Porosity	−2.24	65.78	68.15	0.04*
Silt	−12.52	19.33	24.96	<0.001*
Clay	1.32	32.21	31.62	0.20
Sand	5.52	48.06	43.42	<0.001*

*Significant at p<0.05

Cation exchange capacity (CEC) and Effective Cation Exchange Capacity (ECEC)

High cation exchange capacity (CEC) was observed for farmland (5.01mg/kg) and forestland (5.78mg/kg) (Figure 1). This suggests that high CEC in soils can retain vital elements for plant uptake, such as calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+), and ammonium (NH_4^+), The results of ECEC in the farmland (4.78) and forestland (4.75) were similar to the one reported by Affinnih*et al*. (2014) in their ‘methods of available potassium assessment in selected soils of Kwara state, Nigeria', particularly in Omuaran (5.27). The balance of exchangeable cations Ca, Mg, and K as well as the soil's cation exchange capacity (CEC) are important determinants of plant growth and development (Yang *et al*., 2023).

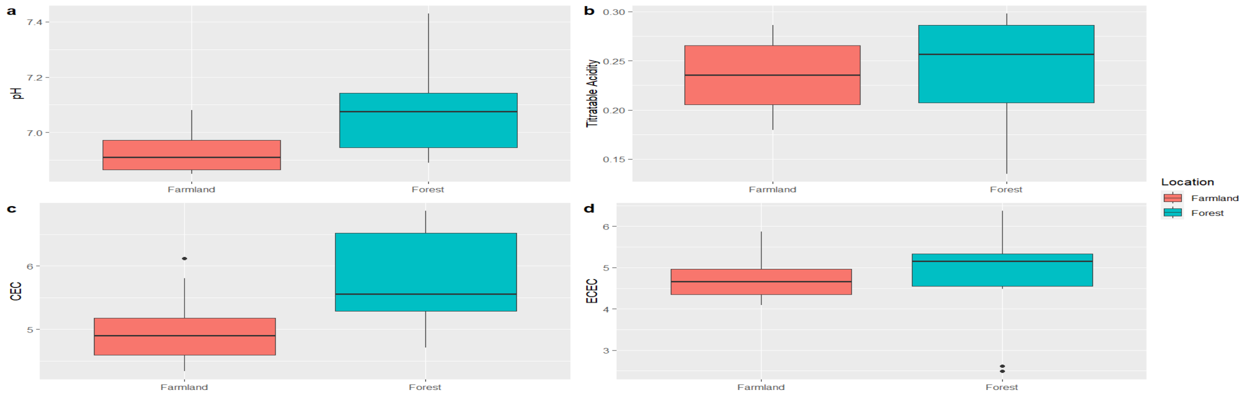

Figure1: Differences in (a) pH (b) Titratable Acidity (c) Cation Exchange Capacity (d) Effective Cation Exchange Capacity of Farmland and Forest

Nitrogen, Potassium and Sodium

Farmland had higher Total Nitrogen (0.27%), Potassium (1.01mg/kg), and Sodium (1.78mg/kg) values compared to forestland soils with 0.19%, 1.15 mg/kg, and 0.22 mg/kg respectively, even though these differences are not significantly different (Table 1) and (Figure 2). This indicates that both land uses have similar and appropriate nitrogen levels, critical for plant growth (Singh *et al*., 2022). However, the higher mean value in farmland might reflect the application of nitrogen-based fertilizers (Walling *et al*., 2019). These results align with that of Minh *et al*. (2023) in their study on clustering analysis of soil environmental quality for perennial crop recommendations in Vinh Long Provincein *Vietnam*An excessively high total N concentration will cause pollution and soil hardness, whilst an inadequate total N level will decrease soil fertility (Ma *et al*., 2022).

Furthermore, the reason for higher potassium observed in farmland soils could be because the distribution of potassium in various soil types can be explained by the differences in the soil's ability to fix and release potassium, which is controlled by cropping strategies and fertilizer use patterns. In Malete, the farmers engage more in the use of fertilizers formulated with nitrogen (N), phosphorus (P), and Potassium (K) perhaps this could be an added advantage concerning potassium. This result contradicts the one reported by Affinnih*et al*. (2014) where different methods were used in the determination of available potassium in selected soils of Kwara state, Nigeria. For the majority of crops in Nigeria, the critical K-level recommendation ranged from 0.21 to 0.30 cmol kg^{-1} (FFD, 2011). The results in this research are below the permissible level for healthy soil in Nigeria. Soils with exchangeable K less than 0.13 cmol kg^{-1} have been classified as being poor in K, and those that contained K range of between 0.21-0.30cmol kg^{-1} are moderately endowed while those above 0.30 are classified as adequate (FFD, 2011)

Titratable Acidity

Titratable acidity was not significantly different between the two habitats (Table 1). Notwithstanding the observed variations in the values, statistical analysis reveals that the differences are not statistically significant, suggesting that the observed variances may result from random variation rather than a substantial ecological difference.This could imply that the acid-neutralizing capacity of the soils in both land types is comparable and decent, this could imply a balanced soil buffering capacity in both environments (Lu*et al*.,2021). Titratable acidity in soils typically ranges from 0.2 to 1.5 mg/kg (Sastre*et al*., 2018; Ferreira *et al*., 2020) while in agricultural soils, titratable acidity is usually between 0.2 to 1.2 mg/kg according to Lu *et al*. (2021). Hence titratable acidity is always influenced by factors such as crop type, fertilization, and soil management practices.

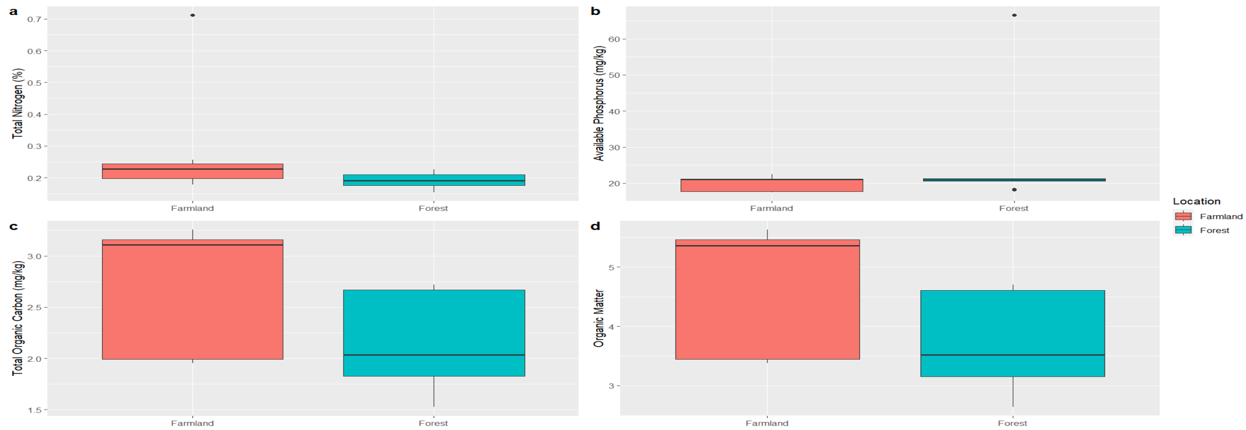

Figure 2: Differences in (a) Total Nitrogen (b) Available Phosphorus (c) Total Organic Carbon (d) Organic Matter of Farmland and Forest

Magnesium and phosphorus

Higher values of Magnesium (2.14 mg/kg) and Available phosphorus (29.52 mg/kg) were observed in forest soils compared to farmland with 1.98 mg/kg and 19.94 mg/kg respectively (Table 1). Adegbite*et al*. (2020) also reported high values of magnesium and phosphorous in their study on the baseline fertility status of a gravelly Alfisol in a derived savannah agroecological zone of Nigeria.

Organic Carbon and Organic Matter

Both total organic carbon and organic matter were significantly higher in farmland (2.70% and 4.66%, respectively) compared to Forestland (2.15% and 3.72%, respectively). This could be attributed to the incorporation of organic fertilizers and crop residues in farmland, enhancing soil organic content. (Liu *et al*., 2015). Both lands are very rich in organic carbon as per the organic carbon fertility map for Nigeria (Ojuola, 2015).To increase the amount of organic matter in the soil, fertilizers are typically used. Humic acid fertilizers or organic fertilizers with a high percentage of organic materials are recommended (Yang *et al*., 2023).

Water holding capacity and soil composition

The same trend was observed with water holding capacity with farmland having higher water holding capacity. The basic soil texture observed in this study was in the order of sand, clay, and silt (Table 1). Farmland soil had a higher composition of sand (48.60%), clay (32.21%), and silt (19.33%) compared to forestland with 43.42%, 31.62%, and 24.96% respectively (Fig 5). These results differ from the one reported by Ojha and Chaudhary (2017), wherepercentage. The result of this research on the textural component of both soil types by percentage differs greatly from that of Adegbite*et al*. (2020) where a very high percentage of sand (78.10-87.1%), clay (4.30-8.30%) and silt (8.60-15.60%) were recorded from baseline fertility status of a gravelly Alfisol in a derived savannah agro-ecological zone of Nigeria.

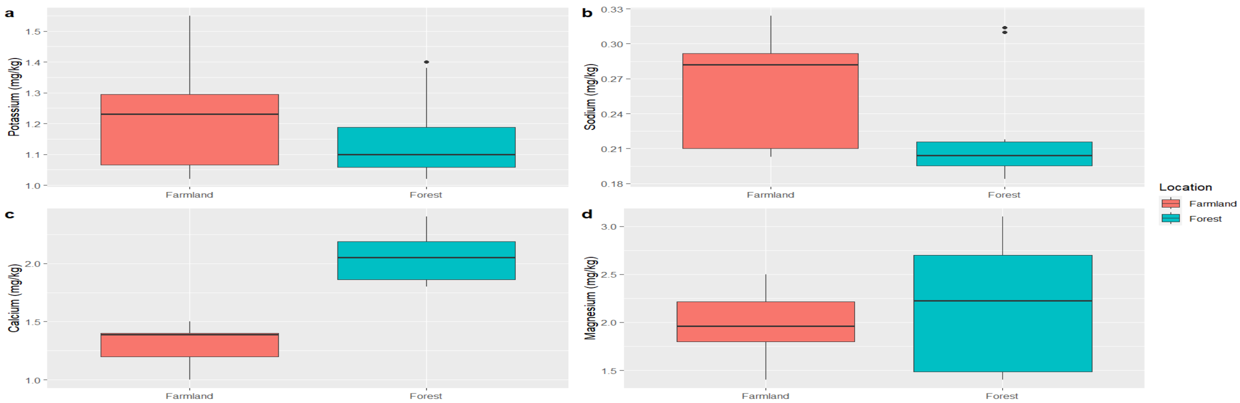

Figure 3: Differences in (a) Potassium (b) Sodium (c) Calcium (d) Magnesium of Farmland and Forest

Lower values of calcium (1.31 cmol kg^{-1}) were obtained in farmland compared to forestland (2.04 cmol kg^{-1}). A similar trend was observed with magnesium (1.98cmol kg^{-1} in farmland and 2.14 cmol kg^{-1} in forestland). These two results for this research conform with that of both Ayodele and Omotosho (2008) and Adegbite*et al*. (2019) who discovered that the two most common elements in savannah soils are Ca and Mg, Maletebeing in the Northern savanna zone of Nigeria. Calcium and magnesium are the most prevalent cations in the soil of the research area (savannah soils); it was suggested that these two variables would fluctuate more than potassium in this investigation as posited by Adegbite*et al*. (2020).

Bulk Density and Soil Porosity

Bulk density was significantly lower in farmland (2.43 g/cm^3) compared to Forestland (2.52 g/cm^3) (Figure 4), indicating soils are more compact compared to farmland, which could be attributed to the undisturbed natureof the forest (Obalum*et al*., 2017). This disagrees with recent studies by Ouyang *et al*. (2020) who stated that bulk density values for soils generally range from 1.0 to 1.5 g/cm^3. Zhou *et al*. (2019) also stated that agricultural soils have bulk densities ranging from 1.2 to 1.8 g/cm^3. Soil porosity was also greater in forest (68.15%) compared to farmland (65.78%) (Figure 5).

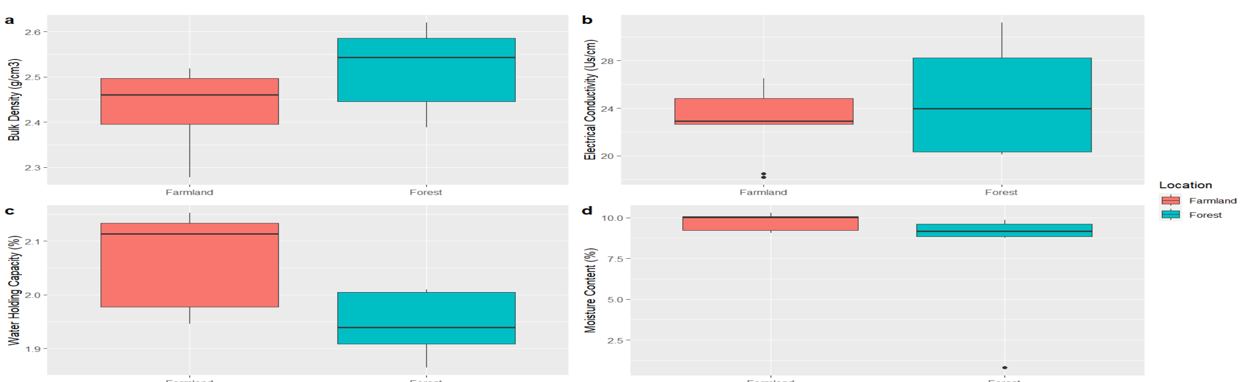

Figure 4: Differences in (a) Bulk Density (b) Electrical Conductivity (c) Water Holding Capacity (d) Moisture Content of Farmland and Forest

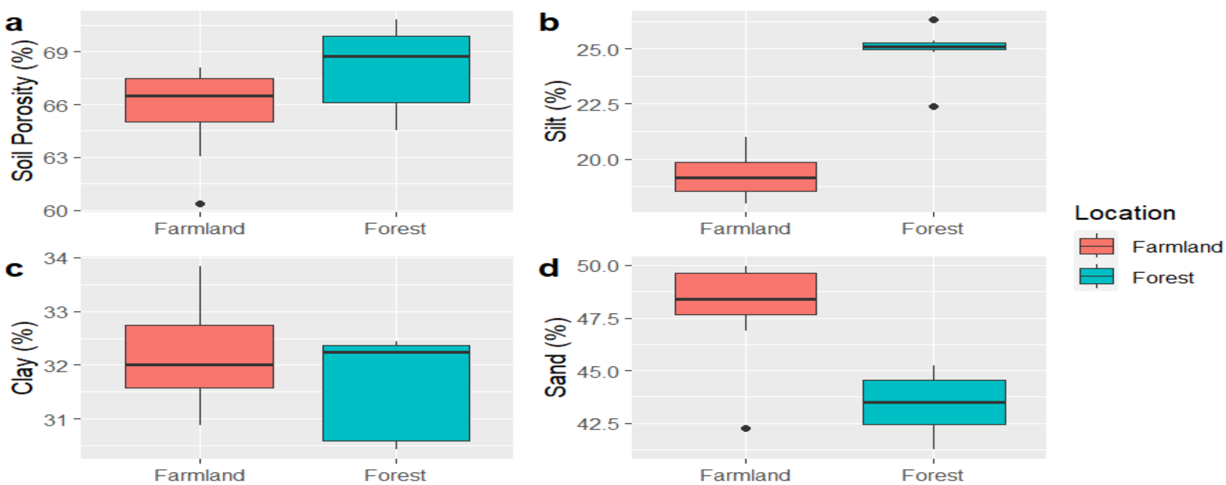

Figure 5: Differences in (a) Soil Porosity (b) Silt (c) Clay (d) Sand of Farmland and Forest

Conclusion

The following soil health indicators were identified in this research: pH, Nitrogen, Potassium, Sodium, Titratable acidity, Magnesium, Available phosphorus, Magnesium, Available phosphorus, Total organic carbon, Organic matter, Water holding capacity, Cation exchange capacity, Soil porosity and bulk density. In comparing forestland soil with farmland soil, forestland soil seems to be generally healthier, according to the soil health indices discussed earlier in this research. Generally, in this research, a neutral pHwas seen in the forestland soil which is preferable to a slightly acidic pHrecorded in farmland soil for the growth of a wide variety of plants. Higher values of magnesium and available phosphorus, both of which are necessary for the growth and development of plants wereobserved in the forestland. Organic carbon and organic matter content were also high, improving soil structure and nutrient availability. As a result of its better physical qualities, higher nutrient retention, and balanced pH, forestland soil is generally healthier for long-term ecological sustainability than farmland soil, even though farmland soil has advantages for agricultural productivity.

Recommendations

Based on the findings, it is recommended:

1. to adopt sustainable land management practices in farmland to enhance long-term soil health. These include the use of organic fertilizers to improve soil organic matter, pH management strategies such as lime application to reduce acidity, and crop rotation to balance nutrient uptake.
2. Enhancing soil structure through reduced tillage and increasing magnesium and phosphorus content with targeted fertilization will promote soil fertility.
3. Forestland soil should be conserved to maintain its ecological benefits, while controlled farming techniques should be implemented to prevent degradation.

References

Abua, M.A and Ajake, A.O. (2013). Assessment of soil quality status under different land use in Apabuyo Local Government, Cross River State. *International Journal of Agriculture Inovations and Research*, volume 2 issue 1, ISSN (Online) 2319-1473.

Adegbite, K.A., Adekiya, A.O., Timothy, O., Adebiyi, V., Alori, E.T., Ejue, W.S., Olayanju, A., & Aremu, C. (2020). Baseline fertility status of a gravelly Alfisol in a derived savannah agro-ecological zone of Nigeria.*Open Agriculture*,5(1):573-581.

Adegbite, K.A, Okafor, M.E, Adekiya AO, Alori, E.T, & Adebiyi, O.T.V. (2019). Characterization and classification of soils of a toposequence in a derived savannah agroecological zone of Nigeria. *Open Agric J*., 13:44–50.

Affinnih, K. O., Salawu, I. S. & Isah, A. S (2014). Methods of available potassium assessment in selected soils of Kwara State, Nigeria. *Agrosearch*, Volume 14(1):76-87.

Auwalu, A., Maunde, M., Onokebhagbe, V.O., Ya'u S.L., Mahmud, A.T., & Nkereuwem, M.E. (2022). Assessment of soil fertility under different land uses at Federal University Dutse teaching and research farm in Sudan savanna agro-ecology of northern Nigeria: Proceedings of the 46th Conference of Soil Science Society of Nigeria; Sustaining Living Soil Ecosystem through Adoption of Soil Management Practices for Mitigating Climate Change for National Development. olloquia Series Available Online at www.sssn.ng Colloquia SSSN 46 (2022).

Bremner, J. M. (1960). Determination ofnitrogen in soil by the Kjeldahl method. *J. Agric. Sri.* 55, With 1 text-figure printed in Great Britain

Bouyous, G. (1947). The Hydrometer as a new and rapid method for determining the colloidal content of soils. *Environmental Science, Agricultural and Food Sciences*: *Soil Science*.

Bray, Y., Roger, H., & Kurtz, l. T. (1945). Determination of Total, Organic, and Available forms of phosphorus in Soils. *Soil Science* 59(1): p 39-46.

CustomWeather. (2024). *Weather data for Malete, Kwara State, Nigeria*. CustomWeather, Inc. Retrieved from http://www.customweather.com.

Cortijos-López, M., Pedro Sánchez-

Ferreira, C.D.S., Da Silva, C. N., Pereira, J. N. D., Rosset, J.S. & Anjos, L.H.C. (2020). Dynamics of soil aggregation and organic carbon fractions over 23 years of no-till management. *Soil and Tillage Research*, Volume 198, 104533.

Herawati, A., Mujiyo, A., Syamshiyah, J., Baldan, S.K & Arifin, I. (2021). Application of soil amendments as a strategy for water holding capacity in sandy soils. IOP Conference Series: Earth and Environmental Science, 724 (1):012014.

Jugulde, A. D., Abdulkadiri, A. & Samaila, D. (2020). Evaluating Soil Fertility Potentials of Some Soils of Bali Local Government, Taraba State, Nigeria. IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS) e-ISSN: 2319-2380, p-ISSN: 2319-2372. Volume 13, Issue 9 Ser., PP 20-25.

Kalra, Y.P. (1995). Determination of pH of Soils by Different Methods: Collaborative Study. *Journal of AOAC International* vol. 78, No.2, pages 310-324.

Khaidem Jackson and Thounaojam Thomas Meetei Influence of soil pH on nutrient availability: A Review. *Journal of Emerging Technology and Innovative Research.* Volume 5:(12) 108.

Kianguebene-Koussingounina, C.E., Olajide-Kayode, J.O., Oyediran, I.A., Kazapoe, R.W., Amuah, E.B.H., Naziru, B., Umaru, A.O. & Addai, M.O. (2023). Geostatistical assessment of soils in Ibadan, Southwest Nigeria: Focus on agricultural lands. *Environmental and Sustainability Indicators*, Volume 19, September 2023, 100287.

Liu, Y., Dell, E., Yao, H., Rufty, T., & Shi, W. (2015). Microbial and soil properties in bentgrass putting greens: Impacts of nitrogen fertilization rates. *Geoderma*, 162, 215-221. doi:10.1016/j.geoderma.2011.02.002.

Lu X, Mao Q, Mo J, Gilliam FS, Zhou G, & Luo Y. (2021). Divergent Responses of Soil Buffering Capacity to Long-Term N Deposition in Three Typical Tropicals with Different Land-Use. *Environmental Science & Technology*, 49(7):4072–4080.

Michael, T. L., Maring, L., Prokop, G., Brils, B., Bender, J., Bispo, A. & Helming, A. (2022). Systems knowledge for sustainable soil and land management. *Science of the Total Environment*Volume 822, 20 May 2022, 153389. https://doi.org/10.1016/j.scitotenv.2022.153389.

Ma. J., Cheng, J., Wang, J., Pan, R., He, F., Yan, L., & Xiao, J. 2022. Rapid detection of total nitrogen content in soil based on hyperspectral technology, *Inf. Process. Agric*., 9(4), 566–574. doi: 10.1016/j. inpa.2021.06.005.

Obalum, S. E., Chibuike, G. U., Peth, S., & Ouyang, Y. (2017). Soil organic matter as sole indicator of soil degradation. *Environmental Monitoring and Assessment*, 189, 176.

Ojuola, O. (2015). Status and challenges of soil management in Nigeria. Retrieved from https://www.slideshare.net/olatunjiojuola/status-and-challenges-of-soil-management-in-nigeria-olatunji-ojuola/53311166.

Ojha, P.K. & Chaudhary, N.K. (2017). Soil Quality Assessment Posed by Industrial Effluents inBansbari Industrial Area of Morang District, Nepal. *Elixir Pollution*106 45906-45908.

Ouyang, W., Hao, F., & Wang, X. (2020). Impact of types on soil physical properties in the Loess Plateau of China. *Ecology and Management*, 474, 118364.

Pagliai, M. (2006): Soil porosity as an indicator of soil health. *Annals of Arid Zone* 45(3):259-286.

Sastre, B., Benito, E., & García, Á. L. (2018). Influence of land use on soil titratable acidity: A study in temperate regions. Catena, 165, 169-178. https://doi.org/10.1016/j.catena.2018.02.022.

Singh, A., Hidangmayum, A., Tiwari, P., Kumar, V., Singh, B.N. & Dwivedi, P. (2022). Sustainable Agriculture: Revisiting Green Chemicals 2022, Pages 99-118.

Sun, Xiao-Lin Minasny, B., Yun-Jin W., Hui-Li W, Xiao-Hui, F. & Gan-Lin Z. (2023). Soil organic carbon content increase in the east and south of China is accompanied by soil acidification, Science of The Total Environment, Volume 857, Part 1, 20 January 2023, 159253.

Tahat, M. M., Alananbeh, K.M., Othman, Y.A. & Leskovar, D.I. (2020). Soil Health and Sustainable Agriculture. *Sustainability* 2, *12*, 4859. https://doi.org/10.3390/su12124859.

Tajudeen, A.F., & Rafiu, F.O. (2017). Soil Fertility and Management PractisesUnder Different Landuse Types in Irepodun Local Government of Kwara State, Nigeria. International Journal of *Ecological Science and Environmental Engineering*2017; 4(6): 109-113 http://www.aascit.org/journal/ijesee.

Van der Laan, E., Nunes, J.D., Dias, L.F., Carvalho, S. & Mendonça dos Santos F. (2023). Assessing the climate change adaptability of sustainable land management practices regarding water availability and quality: A case study in the Sorraia catchment, Portugal. *Science of The Total Environment*, Volume 897, 165438.

Walkley, A. & Black, Y. (1947). Standard operating procedure for soil organic carbon: Walkley-Black method Titration and colorimetric method.

Walling E., Babin A., & Vaneeckhaute C. (2019) Nutrient and Carbon Recovery from Organic (2021). Application of soil amendments as a strategy for water holding capacity in sandy soils Wastes. In: Bastidas-Oyanedel JR., Schmidt *J. (eds) Biorefinery*. Springer, Cham.

Yadav, D.S, Jaiswal, B., Gautam, M. & Agrawal, M. (2020). Soil Acidification and its Impact on Plants, October 2020, DOI:10.1007/978-981-15-4964-9_1, In book: Plant Responses to Soil Pollution (pp.1-26) Edition: 1. Publisher: Springer Singapore.

Yang, M., Zhou D., Hang, H., Chen, S., Liu, H., Su, J., Huilin, L., Jia, H., & Zhao, G. (2023). Effects of Balancing Exchangeable Cations Ca, Mg, and K on the Growth of Tomato Seedlings (*Solanumlycopersicum* L.) Based on Increased Soil Cation Exchange Capacity. Agronomy 2024, 14, 629.

Zhou, W., Huang, W., & Chen, H. (2019). Effects of land use change on soil physical propertiesin a subtropical region of China. *Catena*, 174, 285-293.