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ASSESSMENT OF SOIL PHYSICOCHEMICAL PROPERTIES IN THE PARKLANDS OF NORTHERN NIGERIA

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ABSTRACT: *A study was conducted to examine the soil physicochemical properties and nutrients status in parklands of northern Nigeria. Soil samples were collected using soil auger close to mature trees, tree saplings and seedlings from three states (viz. Bauchi, Jigawa and Kano) in different depths (0–15 cm, and 16–30 cm) and analyzed for soil physical and chemical properties. Soil pH was weakly acidic (5.7–6.0) and not significant (P<0.05). Total Nitrogen, CEC, and Ca all showed no significant difference and decreased with increase in depth. Sand, silt, clay and Mg were statistically different (p<0.05) and decreased with increase in depth. Pearson's correlation matrix revealed significant positive correlations of soil properties with fertility indices. The soils in the agricultural parklands of the states are fairly low in fertility. Mass sensitization and awareness of farmers on best practices that will help improve the soil fertility and nutrients status in the parkland and improve farmers' livelihood are highly recommended. Further evaluations of soil factors are needed to be carried out that will lead to data availability and help in critical evaluation of soil dynamics as well as give an insight to how the fertility and productivity of the soils support and improve biodiversity stability.*

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INTRODUCTION

Soils are naturally occurring physical materials covering the earth's surface and a mixture of organic matter, minerals, gases, liquids, and organisms that together support life. This serves as a natural medium for plant growth (Osuocha *et al.*, 2016). Soil, as an integral element of the natural environment, is a non-renewable resource (Massas *et al.*, 2013). According to Decock *et al.* (2015), the soil is a key component of the earth system as it controls the geochemical, biological, erosional, and hydrological cycles and offers services, goods, and resources for humankind. To Keesstra *et al.* (2016), soils play an important role in global food security, water security, biofuel security, and human health. Soil is a significant determinant of the economic status of nations. Soil ecosystem services fulfill human needs, assigning economic value to things that contribute to human well-being (Robinson *et al.*, 2012). Based on this fact, soil quality has received great attention in recent years (Sinha *et al.*, 2014). Specifically, Khormali *et al.* (2009) refer to soil quality as a concept that includes soil physical, chemical, and biological factors and it is used as a framework for the evaluation of soil quality. The quality of soils does not depend on its ability to supply adequate nutrients alone but the nutrients must be in the right proportion as needed by plants (Ayeni & Adeleye, 2011). In addition, high-quality soils not only produce better food and fiber but also help to establish natural ecosystems and enhance air and water quality (Griffiths *et al.*, 2010). The quality of growth and reproduction of soils cannot be understood without the knowledge of their soil nutrient. The soil and vegetation have a complex interrelation because they develop together over a long period, the selective absorption of nutrient elements by different tree species and their capacity to return them to the soil brings about changes in soil properties (Gairola *et al*., 2012).

The nutrient strength of soil to maintain and support plant growth generally depends on its parent materials. Researchers have reported that the nature of the parent material has been found to influence the development and characteristics of soils (Umeri *et al.*, 2017). The estimation of soil available nutrient contents in a complex heterogeneous system is of great pedological as well as ecological importance (Olojugba & Fatubarin, 2015). Soil nutrients play a central role in the transport and reaction of water, solutes, and gases in soils. Their knowledge is very important in understanding soil behavior to applied stresses and transport phenomena in soils, hence for soil conservation and planning of appropriate agricultural practices (Olorunfemi *et al.*, 2018). A good knowledge of the variations of soil physical and chemical properties and their interactions as it relates to micronutrient status is essential for good land evaluation which is a prerequisite for sound land use planning (Lawal *et al.*, 2013). However, the physical and chemical properties of the soils play an essential role in controlling their fertility status (Ibrahim *et al.*, 2010).

The parklands form the agricultural landscape in the savannah zones of the West African sub-Saharan region where food and cash crops are cultivated under the cover of dominant but sparsely distributed trees (Bayala *et al*., 2015). They provide a range of ecosystem services that enhance livelihood resilience and sustainability among sub-Saharan communities of sub-humid and semi-arid zones (Popoola, 2016). In the Sahel, low organic matter (OM) input is a major limitation to soil fertility improvement and this impedes crop production. To improve soil organic matter, a variety of conservation agriculture practices have been proposed including minimal or no tillage, manure, mulching or maintaining soil cover, and/or diversified crop rotation (Bright *et al.*, 2017). Soil and roots host a wide diversity of

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microbial communities, playing important roles in the decomposition of organic matter, nutrient flow and cycling, and plant health (Dror *et al.*, 2020).

The quality of growth and reproduction of soils cannot be understood without the knowledge of their nutrient status.

METHODOLOGY

The Sudano-Sahelian region is a semiarid zone that coincides with the northern part of Nigeria from latitude 10°N to 14°N and Longitude 4ºE to 11ºE. Its lowest point is around Yelwa in Kebbi State which is about 113 m above mean sea level, while the highest point is around south of Bauchi and west of Kaduna which is over 1000 m above mean sea level (Fig. 1). The climate of this region is highly variable; during the dry season (November–March), the weather is dominated by dusty, dry and cold harmattan winds that originate from the Sahara desert. The wet season occurs from May to October, and it is dominated by moist southwesterly winds that originate from the ocean, which bring abundant moisture inland of the country. This region receives the least amount of rainfall compared to other places in Nigeria, with a mean annual rainfall of about 610 mm. The area features savannah vegetation and a hot semi-arid climate consisting of farmed parkland dotted with patches of shrubs savannah (Kabir, 2011). The major occupation of the inhabitants of this region is farming and rearing animals which makes rainfall extremely important and fluctuation in its characteristics worrisome (Bako *et al.*, 2020).

Sample Collection

Composite soil samples were randomly collected from the plots sampled at a depth of 0–15 cm and 15–30 cm close to the seedlings, saplings, and mature trees using a shovel. The soil samples collected were air-dried, crushed gently, and sieved through 2 mm mesh for laboratory analysis (Akpalu *et al.*, 2020; Muchane *et al.*, 2020). Soil samples from similar depths in each plot were bulked from which composite samples were collected for laboratory analysis.

Laboratory Procedure

Prior to laboratory analysis, the soil samples were air-dried and sieved through 2 mm sieve. The following analyses were carried out:

Following the method in Sobola (2021), fifty-one (51) grams of air-dried soil was weighed into a baffle cup, half-filled with water and 10 ml calgon (neutral sodium hexametaphosphate) was added. The suspension was stirred for 20 minutes by a mechanical stirrer and then washed into 1 litre graduated cylinder. The volume was made up to mark by adding deionized water. The suspension was then shaken vigorously and quickly placed on a flat surface and timed. The temperature was measured at 40 seconds after the shaking; a hydrometer was let down into the suspension to determine silt and clay contents. The suspension was allowed to rest for 2 hours at the end of which the temperature and hydrometer readings were taken to determine clay content. The following calculations were then made:

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% Silt and Clay = $\frac{hydrometer\ reading\ after\ 40\ secs}{51} \times 100$ … ……………………………(1)

% Clay = $\frac{hydrometer\ reading\ after\ 2\ hours}{51} \times 100$ ………………………………………(2)

% Sand = 100 - % Silt and Clay……………………………………………… …….(3)

Determination of Soil Chemical Properties

Soil samples collected from each plot were air dried separately and sieved through 2 mm sieve. Some selected chemical properties were determined. The following are the soil chemical properties examined: Soil pH, Calcium, Magnesium, Phosphorus, Sodium, Potassium, exchangeable cation Nitrogen, soil organic Carbon, and organic matter. Total soil organic carbon (total C) was measured using a modified Walkley and Black chromic acid wet chemical oxidation and spectro-photometric method (Heanes, 1984). Total nitrogen (total N) was determined using a micro-Kjeldahl digestion method (Bremner, 1996). Soil pH in water (S/W ratio of 1:1) was measured using a glass electrode pH meter and the particle size distribution following the hydrometer method (Gee, 2002). Available phosphorus (avail. P), exchangeable cations (K, Ca, Mg and Na) and micronutrients (Zn, Fe, Cu, Mn and B) were analyzed based on the Mehlich-3 extraction procedure preceding micro plasma atomic emission spectroscopy (MP-AES, Agilent 4200, Agilent Inc., USA). Exchangeable acidity (H + Al) was determined by extracting soil with 1N KCl and titration of the supernatant with 0.5M NaOH (Anderson & Ingram, 1993). Effective cation exchange capacity (ECEC) was calculated as the sum of exchangeable cations (K, Ca, Mg and Na) and exchangeable acidity (H + Al).

Results and Discussion

Soil Physico-chemical Properties in the Study Area

The result of physico-chemical properties of the soils in the parklands under study are presented in Table 1 below. The result of particle size distribution indicates that the soil belongs to sandy clay loam textural class in all the parklands of the states. The soil pH measured for the three states was 5.7634, 6.0021, and 6.0292 for Bauchi, Jigawa, and Kano States respectively. The percentage organic carbon and organic matter contents ranged from 0.4914 to 0.5133. The percentage nitrogen of the soils ranged from 0.0435 to 0.0465 and the available phosphorus was found to be 3.8334(mg/kg), 3.4689 and 5.7256 (mg/kg) for Bauchi, Jigawa and Kano States respectively. The exchangeable potassium generally ranged from 0.1895 Cmol (+) kg-1 soil in parklands of Jigawa State to 0.2545Cmol (+) kg^{-1} soil in Kano State. The value of exchangeable calcium was 1.8601, 2.1112 and 2.2085Cmol (+) kg^{-1} soil for Bauchi, Jigawa and Kano States. The cation exchange capacity was 2.7401 for Bauchi, 3.1254 Jigawa and 3.2296 for Kano States respectively.

Table 1: Soil Physicochemical Properties of the Study Area

	Bauchi	Jigawa	Kano	Sig.
Sand	71.1700^{a}	55.2425^{b}	56.6161^{b}	.818
Silt	12.3211^{a}	29.2326	27.2739	.767
Clay	16.5090	15.5249	16.1100	.646
PH	5.7634	6.0021	6.0292	.210
E.C (Us/cm)	139.8277	149.0434	135.9573	.291

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O.C (%)	0.5082	0.5133	0.4914	.756
N (%)	0.0465	0.0446	0.0435	.571
P (mg/kg)	3.8334	3.4689	5.7256	.240
Ca (cmol (+)/Kg)	1.8601	2.1112	2.2085	.409
Mg (cmol(+)/Kg)	0.5465a	0.7148b	0.6430	.122
K (cmol(+)/Kg)	0.2273	0.1895	0.2545	.342
Na (cmol(+)/Kg)	0.0831	0.0851	0.0806	.720
E.A (cmol(+)/Kg)	0.0232	0.0262	0.0417	.225
C.E.C (cmol(+)/Kg	2.7401	3.1254	3.2296	.326
Zn(mg/kg)	13.5213	7.6960	5.0512	.074
Cu (mg/kg)	2.8002	2.4630	2.4183	.485
Mn (mg/kg)	27.3326	28.3692	22.8647	.273
Fe (mg/kg)	193.5905	154.0576	173.8805	.360

Values followed by different superscripts along the rows indicate significant difference ($p<0.05$).

DISCUSSION

Soil physical properties play a significant role in soil fertility because the amount and sizes of soil particles determine the porosity and bulk density which account for nutrients retention or leaching of nutrients (Azeez *et al.*, 2020). The results from the sampled locations indicated that sand, silt, and clay contents of the soil ranged from 55–71%, 12–29.2%, and 15–16% respectively, and were found to differ statistically ($p \leq 0.05$) along the locations. The size distribution directly influences the porosity which is highest for sand as is expected because sand cannot retain water. This finding conforms with the findings of Adugna and Abegaz (2016) and Azeez *et al*. (2020) who in their various studies of forest soils found sand content to be high. This finding agrees with that of Atiku and Noma (2011) in their study of Physicochemical Properties of the Soils of Wassaniya Forest Reserve, Tangaza Local Government, Sokoto State. Adamu *et al*. (2022) found the textural classes of the soils in the farmlands of Bunkure Local Government Area, Kano State to be loamy sand under *Azadirachta indica, Diospyros mespiliformis, Vitellaria paradoxa, Tamarindus indica, Mangifera indica, Adansonia digitata* and sandy loam under *Eucalyptus camaldulensis* and *Moringa oleifera*. Abbasi *et al*. (2007) opined that variation in soil texture amongst land use types implies the effects of land use types on soil properties which are triggered by different utilization and management systems of land use types.

The pH is recognized as a principal variable in influencing virtually every process in the soil system. The health of crops and other soil life, the availability of nutrients, and the activity of pesticides are all affected by pH (Omar, 2012). From this study, the pH range of soil samples was 5.76–6.00, indicating that the soils were weakly acidic and not significantly different ($p \leq 0.05$). This is similar to that reported by Yekini (2021) who obtained 4.4 to 8.20, indicating that the soils were moderately acidic to moderately alkaline and not significant ($p \leq 0.05$) among sampled locations in Adamawa State. This pH range is similar to that reported by Dishan (2016) in his study of Nutritional values and diversity of wild fruit trees with soil nutrient flux in Adamawa flood plains, and Umeri *et al.* (2017), who evaluated the physical and chemical properties of some selected soils of rain forest zones in Delta State, reported that the soils had a pH range of 4.72 to 6.52 at the surface. This is also in conformity with the

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findings of Shafi'u (2007) who evaluated some physico-chemical properties of some fadama soils in Bauchi State, and reported that the soils were mostly clay-loam in texture and slightly acidic (PH=5.55). Conversely, this pH range differs from pH range reported in a forest by Atiku and Noma (2011), Umar *et al*. (2020) and Abdulkadir *et al*. (2022). These findings conform with that reported by Jimoh *et al.* (2019) in their study of the evaluation of soil quality under a date palm plantation for climate change and food security in Gombe State University, Gombe Nigeria, where the mean pH of soil stood at 6.33 at upper slope and 6.34 at middle slope. This variation may perhaps be attributed to differences in ecozones and litter accumulation from leaf drops. Soil pH influences nutrient uptake and hence tree growth, and a pH of 6.5-7.0 generally provides the best-growing conditions and may be responsible for the ability of the parklands to fairly accommodate or sustain a reasonable number of species despite limitations in terms of good management practices (Londo & Carter, 2002).

Organic carbon and organic matter content ranges were low but were found not to differ significantly with location ($p \leq 0.05$). The organic carbon which is an index of the soil organic matter differs among the different study sites, likewise the organic matter. These values were relatively low compared to the values of Atiku and Noma (2011) in their study of the Physicochemical Properties of the Soils of Wassaniya Forest Reserve, Tangaza Local Government Area, Sokoto State which ranged from 3.72 to 7.11 g/kg and 6.41 to 12.26 g/kg respectively, and Isah *et al*. (2014) in their study on the Soil Status of Kogo Forest Reserve in North-Western Nigeria which ranged from 1.0, 7.38, 11.57 and 8.42 g/kg at Wassaniya, Jimajimi, Yartagimba, and Daiji areas respectively. In the savannah ecosystem of Kano State, Salisu and Rabi'u (2019) reported organic carbon and organic matter contents slightly above what is obtained in this study. The results are also lower than that reported by Olorunfemi *et al.* (2018) at the forest vegetative zone of Nigeria. This could be due to the lower microbial count that could undertake litter decomposition or low moisture that will enhance the microbial activity in the parklands. This implies the availability of ample litter cover, organic inputs, root growth and decay, and abundant burrowing fauna accounts for the variation.

Total Nitrogen values were lower and were not statistically different ($p > 0.05$) across the parklands. Several factors that result in the fragmentation of forests such as grazing can reduce soil organic carbon, total nitrogen, and soil pH (Dingpeng *et al.*, 2014). This can be attributed to the removal of aboveground biomass due to grazing, logging, firewood collection, and deterioration of soil physical parameters. The changes in SOC and Total Nitrogen vary across disturbance regimes, soil layers, and locations due to climatic, edaphic, biological, land management practices, vegetation cover, aspect, and topography (Birhane *et al*., 2017), and such changes affect the overall productivity of the ecosystems (Chen *et al.*, 2015).

The CEC of the parkland showed no significant difference ($p \leq 0.05$) and decreased with an increase in depth, the values ranged from 2.1 to 3.78 cmol/kg. The result is slightly lower than that of Muhammad *et al.* (2020) who in a study to assess the spatial variability of soil samples collected from three different land use (reserved area, parkland, and farmland) around Baturiya Sanctuary, northwestern Nigeria reported CEC value of 4.5 cmol/kg. The result is not in agreement with that of Isah and Shinkafi (2000), who reported 5.1 cmol/kg; Bishir (2012) reported the values as 5.50 to 5.85 cmol/kg at Kogo. According to Camberato (2001), the clay or organic matter content is the primary factor determining CEC in soil, which indicates the soil's potential to hold plant nutrients and make them readily available for plant absorption. The exchangeable bases (Mg, K, and Na) of the parkland were all not

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statistically different ($p<0.05$), except for Mg; the values decreased with an increase in depth. Isah and Shinkafi (2000) recorded higher values for K and Na, which were 4.17 and 4.72 cmol/kg respectively, compared to the findings of this work. This result is in variance with the findings by Abba *et al.* (2014) in their study of Soil Physico-Chemical Characteristics of Kanawa Forest Reserve (KFR), Gombe State, Nigeria. Umeri *et al.* (2017) evaluated the physical and chemical properties of some selected soils of rainforest zones in Delta State and reported exchangeable Ca, Mg, and ECEC. Zinc, Fe, Cu, and Mn contents were found to be adequate based on established critical levels for the various nutrients. Potassium levels were found to be deficient in the soils. These results could be a result of differences in the parent material of the soils or climatic factors that can induce mobilization and immobilization of these cations. The exchangeable Ca was higher at the surface soil depth than at the subsurface soil depth. This could be as a result of soil parent material primarily rich in basic cations and the divalent cations which are retained in higher concentrations and for longer periods by the soil colloidal particles because of their higher selectivity coefficient over the monovalent cations. This is contrary to the work of Kiflu and Beyene (2013) who revealed that the exchangeable Ca contents of soil was higher on the surface soil layer than the subsurface soil layer due to the association of biological accumulation with biological activity and accumulation from plant residues. Mg, which was significantly different among the exchangeable bases, could be as a result of higher porosity and higher moisture content which can influence leaching or as a result of exchangeable bases cations between soil and plant. This confirmed the results of Tanimu *et al*. (2013) which showed that the growth of roots in the soil leads to short-term acidification of the soil through the removal of base cations such as Ca, Mg, and Na in exchange for hydrogen ions.

In consideration of the study area (Sudano-Sahelian region) in which the trees are scattered, coupled with human disturbances in terms of overexploitation of the tree species which had already exposed the soil and of course changed the soils in terms of structure, moisture content, and possibly micro fauna and flora, regeneration can be negatively affected by the soil in one way or the other in terms of nutrient cycling and fertility.

CONCLUSION

It is therefore concluded that the soils in the agricultural parklands of the region are fairly low in fertility, indicating the need for mass sensitization and awareness of farmers on best practices to improve soil fertility and nutrient status. The study also highlights the importance of further evaluations of soil factors to support biodiversity stability and the need for interventions to improve soil fertility and nutrient status in the parklands of northern Nigeria.

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