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Physio-Chemical Properties of Soil in Ganawuri, Plateau State, Nigeria

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Abstract

Increased food production is necessary for the fast growing population in the world. Soil health is associated with sustainable agriculture therefore the need to improve soil fertility and health is imperative. Sample of four soils were randomly selected at depth of 0-20cm for surface and 20-40cm for sub-surface. These sampled soils were taken and tested in the laboratory to determine their physio-chemical properties using various methods, based on the objectives. Results revealed that the soil colour shows a dark yellowish brown (10YR $^{3}/_{6}$) for sub-face, yellowish brown (10YR $^{5}/_{4}$) are seen under wet condition, and for the surface are brown (10YR $^{5}/_{3}$) and sub-surface are very pale brown (10YR $^{6}/_{3}$) under dried condition. The soil structure of the study area was found to be loamy sand at the surface and sub-surface. However, study revealed that soil pH is slightly acidic in nature and calcium chloride pH is moderately alkaline. Organic matter is moderately found. Nutrients such as potassium, nitrogen, phosphorus, sodium, magnesium are low in the sampled soil. Total Exchangeable acidity (TEA) indicated a minimal quantity of aluminum and hydrogen (H) concentration. Electrical Conductivity shows that the soil is not saline in nature. The study therefore recommends crop rotation and agroforestry as well as addition of manures to improve the physio-chemical properties and soil fertility.

Keywords

Agriculture, Soils, Physical Properties, Chemical Properties, Texture, Nutrient

1. Introduction

Agricultural establishment depends predominantly on soil, and serves as a means of providing food security, raw materials for industries and provides occupation for the rural and urban settlers [1]. The greatest challenges facing nations of the world today are the provision of adequate food and other basic needs of the citizenry on a sustained based. With the ever-growing human population, the need to produce more food to meet up the need of the world ever teaming population has become more urgent today than ever before [2]. Soils are the fundamental resource supporting agriculture and forestry, as well as contributing to the aesthetic of a green plant. By supporting plant growth, soil becomes a major determinant of atmospheric composition and therefore earth's climate. Soils store two or three times more carbon than they exist in the atmosphere as CO_2 [3].

Soil, the uppermost layer of the earth's crust is one of the most important natural resources that exist since it is the basic sustaining life on the planet. Soil may be defined as a thin layer of earth's crust, which serves as a natural medium for growth of plant. Soil differs from the parent material in the morphological, physical, chemical and biological properties [4]. Soil is a vital component, it forms the life layer of plants. Soil developed as a result of pedogenic processes through weathering of rocks, consisting of inorganic and organic constituents of both chemical, physical, mineralogical and biological properties [5]. All gifts of nature none is more indispensable to man than the soil, this is because it has served as the source for most or all his basics needs of food, shelter and clothing as well as source of other raw materials. This is an indication that human life and its sustenance on a long-term basis is dependent on the quality of soil [1].

According to FAO [6] soil classification and characteristics reported that soil can be characterized by its texture, colour, structure, consistency and abundance of roots, rocks and carbonates. Soil quality includes a capacity for water retention, carbon sequestration, plant productivity, water remediation. Soil comprises of minerals, soil organic matter, air and water. The composition and proportion of these components have great influence on the soil physical properties including texture, color, porosity and structure. In turn, these properties affect air and water movement in the soil and also play a role in soil processes [7].

Soil texture has impact on some soil physical and chemical properties which includes infiltration and retention of water, soil aeration and absorption of nutrients, microbial activities, and tillage and irrigation practices [8]. It is also an indicator of features such as type of parent material, homogeneity and heterogeneity within the profile, migration of clay and intensity of weathering of soil material or age of soil [9, 10].

The nature, size, and distribution of natural aggregates of soil play a very important role in determining such soil physical conditions and characteristics as pore space, water retention and movement, infiltration, porosity and aeration, heat transfer, strength and erodibility [11]. Ashenafi [12] states that friable consistency of soils indicates soils are workable at appropriate moisture content and lack of very stick and very consistency. It describes the action of physical forces of cohesion and adhesion on the attributes of soil material at these moisture contents that determines the resistance of soil material to crushing or rupture and its ability to change the shape or to be molded. Hossain, Rodrigue and Johnson [13] stated that the alternate wetting and drying conditions in the soil resulted in the reduction and subsequent release of iron oxides, which were accumulated in the form of brown, light olive brown, dark brown and dark yellowish-brown matters in the middle zone of the profiles. Dark colour (low chroma) of soils could be related to the strong impregnation of profile by organic matter during pedogenesis or due to prolonged water logging [14]. Any factor that influences soil pore space will also affect the bulk density. Woldeamlak and Stroosnijder [15] and Mulugeta [16] revealed that the bulk density of cultivated soils was higher than the bulk density of forest soil. Soil bulk density increased in the 0-10 and 10-20cm layers relative to the length of time the soils were subjected to cultivation [16].

Total porosity of soil usually lives between 30 percent (in compacted subsoil) to 70 percent (in well-aggregated, high- OM surface soils) [17]. The study further indicates that porosity could be general indication of the degree of compaction in a soil in the same way as bulk density is used. As is the case with bulk density, management exerts a decisive influence on the pore space of soils.

Most chemical interactions in the soil occur on colloid surfaces due to their charged surfaces. As a result of their chemical makeup and large surface area, colloids have charged surfaces that are to sorb, attract, ions (charged particles) within the soil solution. Soil with high pH tends to affect plants by reducing the amount of manganese and iron in the roots zone [18]. Furthermore, low pH tends to affect plants harmfully through increasing the amount of aluminum, manganese [17].

Organic matter plays a vital role in increasing water holding capacity of the soil and the proportion of water available to plants for growth [19]. Organic matter found on the soil surface helps to protect the soil from the effect of wind, rainfall and sun [20]. In all forms of agricultural systems, whether tradition or modern, soil organic matter plays an essential role in sustaining crop production and preventing land degradation [21]. Cation nutrients include: iron (Fe), hydrogen (H^+), calcium (Ca^{2+}), magnesium (mg^{2+}), potassium (k^+) and sodium (Na^+) high cation exchange capacity is a good measure of a soils ability to retain and supply nutrients to plants [22].

The exchange capacity of anions increases as soil pH decreases. Most agricultural soils have small anion exchange capacity compared to cation exchange capacity, because anions are constantly repelled by negatively charged clay particles and organic matter [23]. Electrical conductivity is also a very important property of the soil, it is used to check the quality of the soil. The electrical conductivity of a soil solution increases with the increased concentration of ions [24].

The aim of this study is to examine the physio-chemical properties of soil in Ganawuri, Plateau State. Based on this goal, this study was achieved through the following objectives: to determine the physical properties of soil status and examine the chemical properties of soils. Therefore, the focus on understanding the aim is well deserved to suggest measures that will help know the characteristics of soil, its physical, chemical and biological properties. This is because these factors influence the fertility of the soil and its arrangement.

2. Materials and Methods

The study was conducted within in Ganawuri district, Plateau State. Four areas were selected for the study; Fangroi, Dading, Bum and Tsogong of Ganawuri. The study area lies between latitude 9'38'00"N and longitude 8'46'00"E 9’63333'N and 8.76667'E Figure 1. It has an area of 807km^2 and a population of 131,557at the 2006 census. A total of four (4) soil samples were collected using random soil sampling method. Samples were collected at depth of 0-20cm for surface and 20-40cm for sub-surface soil, using soil auger, the soil sample was collected in a well label polythene bag and brought to laboratory for routine analysis.

The collected soil samples were air-dried in the laboratory.Wet soil colour was determined in-situ using Munsell Colour Chart. The dried samples were crushedusing wooden pestle and mortar and sieved to pass through 2mm sieve.The particle size of the sample size was determined using the Buoyocuos hydrometer method as used by Gilbert [25] and Jiswal [26]. The texture of the soil was obtained by applying the result of the particle size distribution to the Marshall's textural triangle. Moisture content was determined using the gravimetric method [27]. The pH of the soil was measured in a 1:2:5 soil-water suspension ratio and also in 0.01M$CaCl_2$ using a glass electrode pH meter [26]. The electrical conductivity of the soil samples was measured alongside pH with an EC meter using the same soil-water suspension 1:2.5 used for measuring the soil pH in water [26]. Value of organic matter was obtained by multiplying the organic carbon content of the soil by a factor of 1.724 [28]. In this method, organic carbon was oxidized by potassium dichromate ($K_2Cr_2O_7$) in the presence of sulphuric acid (H_2SO_4) and the carbon was titrated with 0.5N ferrous sulphate using diphenylamine indicator [26].Total nitrogen content of the samples was determined by the Kjeldahl wet oxidation method [29]. The available phosphorus content of the samples was determined by bicarbonate extraction method for near neutral and slightly alkaline soils (30). The exchangeable cation content of the soil samples was done by extracting in 1N neutral ammonium acetate (NH_4OAc). The exchangeable calcium and magnesium contents of the soil were determined by titrimetric method while the exchangeable potassium and sodium was determined by the flame photometer method [27]. The cation exchange capacity (CEC) of the soil samples was determined by neutral normal ammonium acetate displacement method while TEA was carried out by displacement with KCL and titrating the extract with 0.025N NaOH solution using phenolphthalein indicator [27].Correlation analysis was used to compare the fertility status of the soils using the formula.

$$correlation(r) = \frac{\mathrm{SPx1.x2} - \mathrm{x1.x2/n}}{\sqrt{\mathrm{SSx1.SSx2}}}$$

SP = Sum Products SS = Sum of Squares; n = Number; x= variable

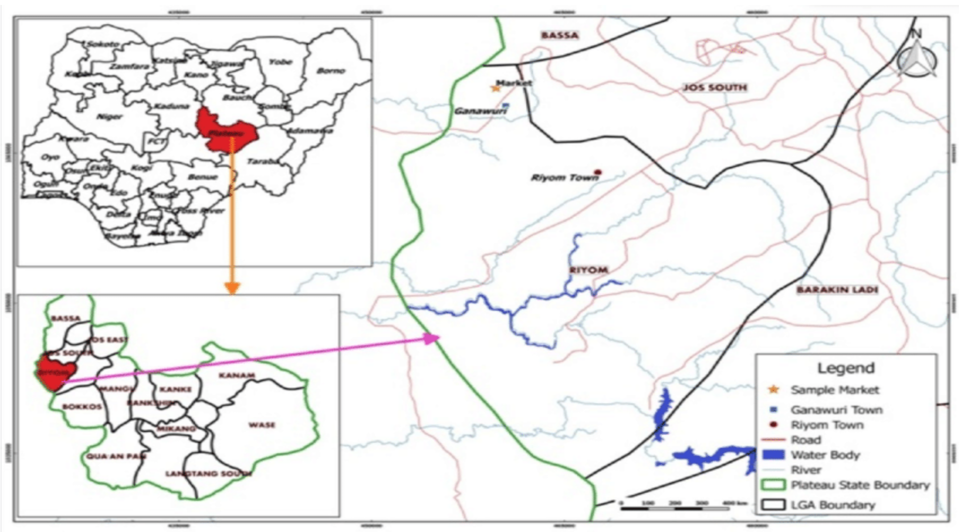

Figure 1. Map of Nigeria showing the study Area.

3. Results and Discussion

3.1. The Physical Properties of the Sampled Soil

3.1.1. Particle size or soil texture of the sampled soil

The results in Table 1, shows that the percentage of clay, silt and sand ranged from 8.60% - 9.10% with the mean value of 8.85%, for clay at 0-20cm and 7.88% - 11.60% with the mean value of 9.74% for clay at 20-40 cm, silt ranged from 8.28%-10.78 % with the mean value of 9.53% for silt at 0-20cm and 7.78% - 8.50% with the mean value of 8.14% for silt at 20-40cm. Sandy, it ranged from 83.12% - 80.12% with the mean value of 81.62% for sandy at 0-20cm and 80.62% - 83.62% with the mean value of 82.12% for sandy at 20-40cm. The textural class of soil of the studied areas is loamy sand. According to Choudhary [31] and Hillel [32] soil texture is the relative proportion of the different particle size fractions, specifically referred to as sand, silt and clay (with organic and cementing materials removed). As seen in this study, the sampled soil had a relative proportion of sandy, clay and silt. Furthermore, it is also an indicator of some other related soil features such as type of parent material, homogeneity and heterogeneity within the profile, migration of clay and intensity of weathering of soil material or age of the soil [33, 34].

3.1.2. Soil Colour

The result of the soil colour as presented in Table 1, shows that they are: dark yellowish brown(10YR $^3/_6$), and for sub-face are: yellowish brown (10YR $^5/_4$) under wet condition, and for the surface are brown (10YR $^5/_3$) and sub-surface are very pale brown (10YR $^6/_3$)under dried condition. Dengiz, Zaglam and Sarioglu [35] opined that, dark color soils are related to strong impregnation of profile by organic matter during pedogenesis or due to prolonged water logging. The surface are yellowish brown (10YR $^3/_6$), pale brown (10YR $^6/_3$), yellowish brown (10YR $^5/_4$) and pale brown (10YR $^6/_3$) under dried condition. This indicate that the soil texture is averagely loamy sand for surface and sub-surface, the soil is slightly sticky and all are sticky for sub-surface and generally granular in structural form.

Table 1. Physical and morphological properties of the sampled soil

Sampling Depth (cm)	Particle Size Distribution			Textural class	Colour			
	Clay%	Silt%	Sandy%		Wet Code	Colour Description	Dry code	Colour Description
A1 0-20cm	8.60	8.28	83.12	Loamy Sand	10 YR 3/6	Dark Yellowish Brown	10 YR 5/3	Brown
B2 20-40cm	11.60	7.78	80.62	Loamy Sand	10 YR 5/4	Yellowish Brown	10 YR 6/3	Pale Brown
A1 0-20cm	9.10	10.78	80.12	Loamy Sand	10 YR 3/6	Yellowish Brown	10 YR 6/3	Pale Brown
B2 20-40cm	7.88	8.50	83.62	Loamy Sand	10 YR 5/4	Yellowish Brown	10 YR 6/3	Pale Brown
Mean 0-20cm	8.85	9.53	81.62					
Mean 20-40cm	9.74	8.14	82.12					

3.1.3. Soil Structure

As shown in Table 1, the soil structure of the study area is averagely loamy sand for surface and sub-surface, the soil is slightly sticky, non-sticky, slightly sticky for surface, and all are sticky for sub-surface and generally granular in structural form. After the laboratory analysis, which was determined by using the textural classes, it was found to be loamy sand at the surface (0-20cm) and sub-surface (20-40cm). The nature, size, and distribution of natural aggregates of soil play a very important role in determining such soil physical conditions and characteristics as pore space, water retention and movement, infiltration, porosity and aeration, heat transfer, strength and eroding capacity [32]. Soil hydrophobicity causes soil water repellency, which determines the infiltration of water into the soil, this controls precipitation and contribute to surface run-off or flooding [36]. Large-particle soils increase the levels of hydrophobicity [37]. The structure of the studied area as shown in Table 1 is loam-sandy in structure; this implies that it can have high hydrophobicity. However, this is not universal; as in some cases, clay-rich soils also present high levels of hydrophobicity.

4. Chemical Properties of Sampled Soil

4.1. Soil pH, organic matter, total nitrogen, magnesium and phosphorus available

Soil pH: as shown in Table 2, the surface ranges from 2.89 to 5.85 with the mean value of 4.37, the sub-surface range from 5.86 to 5.86 with the mean value of 5.86, this shows that the soil is slightly acidic in nature.

4.2. Calcium chloride pH of the soil ranges from 4.62 to 4.90 with the mean value of 4.76 and sub-surface range from 4.91 to 4.89 with the mean value of 4.9 this indicates that the soil is moderately alkaline. According to [38], soil that is slightly acidic to alkaline in nature provides best growing condition and influences the uptake of nutrients by plants. Soil pH strongly influences soil processes such as nitrogen cycling by affecting the soil chemical, physical and biological processes [39].

4.3. Soil organic matter

The surface ranges from 2.80% to 2.20%with the mean value of 3.9% (Table 2), sub-surface range from 3.10% to 1.90% with the mean value of 2.5%, the organic matter content of all auguring unit which indicated that the soil is moderately evaluated. Study by Bockheim, Gennadiyev, Hartemink and Brevik [40] revealed that soil organic matter content is the rich-mineral constituent which improves plant growth. It plays a huge role in the soil texture, water retention and contributes to soil nitrogen, sulphur, phosphorus and cation capacity and exchangeable cation.

4.4. Potassium (K)

The surface ranges from 0.20 cMol/kg to 0.17 cMol/kg with the mean value of 0.185 cMol/kg, also the sub-surface range from 0.18 cMol/kg to 0.15 with the mean value of 0.165 cMol/kg, the potassium of all auguring points indicated that the soil is low (Table 2).

Table 2. Chemical properties of the sampled soil in the study area

Sampling depth (cm)			Ppm	%		ppm	cMol/Kg					
	pH(H_2O)	pH($Cacl_2$)	EC	OM	N	P	K	Na	Ca	Mg	EA	CEC
A1 0-20cm	2.89	4.62	43	2.80	0.013	34	0.20	0.030	2.00	2.20	1.37	5.80
A2 20-40cm	5.86	4.91	22	3.10	0.014	37	0.18	0.028	2.20	3.10	1.32	4.81
B1 0-20cm	5.85	4.90	30	2.20	0.013	38	0.17	0.029	1.80	2.00	1.39	5.39
B2 20-40cm	5.86	4.89	27	1.90	0.013	35	0.15	0.026	1.50	1.60	1.40	4.68
Mean 0-20cm	4.37	4.76	58	3.9	0.013	58	0.185	0.0295	1.9	2.1	1.38	5.595
Mean 20-40cm	5.86	4.9	24.5	2.5	0.0135	36	0.165	0.027	1.85	2.35	1.36	4.745

Key: EC = Electrical Conductivity OM = Organic Matter N = Nitrogen Na = Sodium Mg = Magnesium P = Phosphorus, K = Potassium EA = Exchangeable Acidity Ca = Calcium CEC = Cation Exchange Capacity

4.5. Sodium (Na)

The surface ranges from 0.030 cMol/kg to 0.029 cMol/kg with the mean value of 0.0295 cMol/kg and the sub-surface free range from 0.028 cMol/kg to 0.026 cMol/kg with the mean value of 0.027cMol/kg the sodium of all auguring points which indicated that the soil has low amount of Sodium.

4.6. Magnesium (Mg)

The surface ranges from 2.20 cMol/kg to 2.00 cMol/kg with the mean value of 2.1 cMol/kg and the sub-surface range from 3.10 cMol/kg to 1.60 cMol/kg with the mean value of 2.35 cMol/kg the magnesium of all auguring points indicated that the soil is in medium. High values of nitrogen, phosphorus and magnesium is attributed to high content of organic matter in the soil [41].

4.7. Nitrogen (N)

The surface ranges from 0.013% to 0.013% with the mean value of 0.013%also the sub-surface range from 0.014% to 0.013% with the mean value of 0.0135%, the nitrogen at auguring point indicated that the soil is low in nitrogen (Table 2). Nitrogen content contributes to the nutrient of the soil, this is to say that the soil in the sampled areas have poor nutrient due to the limited content in Nitrogen [42].

4.8. Phosphorus (P)

The surface ranges from 34% to 38% with the mean value of 58% and the sub-surface range from 37% to 35% with mean value of 36% the phosphorus of all auguring unit which indicated that the soil is very low.

4.9. Total Exchangeable acidity cMol/100g (TEA):

The surface ranges from 1.37 cMol/kg to 1.39 cMol/kg with the mean value of 1.38 cMol/kg, also the sub-surface range from1.32 cMol/kg to 1.40 cMol/kg with the mean value of 1.36 cMol/kg the exchangeable acidity of all auguring points which indicated that the soil is minimal in aluminum and hydrogen concentration. Previous study by Khadka [43] reveals that exchangeable cations, nitrogen, phosphorus and micro-nutrients correlates with organic carbon and soil organic matter thus improving soil nutrient.

4.10. Electrical Conductivity

The exchangeable cation of the soils of the studied areas had the surface range from 30 ppm to 43 ppm with the mean value of 58 ppm and for the sub-surface range from 22 ppm to 27 ppm with the mean value of 24.5 ppm the exchangeable cation of all mapping unit which indicates that the soil is not saline in nature. From the result obtained it an indication of non-salinity from the sampled areas. This indicator of good yields from the soil as studies showed that salinity of 10 mMNaCl reduced the yield of *Triticum aestivum* up to 65% [44]. Increased salinity level in the root medium reduces the uptake of K, Ca, and Mg which disrupts stomatal conductance and transpiration rate [45, 46].

5. Conclusion and Recommendations

This study concludes that the physical structure of the soil in the sampled areas is mainly loam-sandy soil in texture with a relative proportion of sand, silt and clay. The sampled soil has high porosity but little bulk density. The chemical property of the sampled soil revealed that the pH level of the soil is slightly acidic and moderately alkaline in nature. It is also not saline in nature, these indicators indicates that the soil provides a good condition for farming. The study further revealed that the soil is rich in organic matter although limited in nutrients like nitrogen, potassium, phosphorus, sodium.

This study therefore recommends traditional and mechanized agricultural practices to improve the soil sampled in Ganawuri. They include traditional practices such as agroforestry to control the climate of the sampled area, crop rotation which is the cycling of crops to improve soil health and fertility. Mechanized practices such as tillage, to improve the bulk density and porosity of the soil in the sampled areas, addition of fertilizers and manure to improve the nutrients of the soil thus improve the soil.

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