ASSESSMENT OF SOIL PHYSICAL AND CHEMICAL PROPERTIES UNDER VEGETABLE CULTIVATION IN ABUJA METROPOLITAN AREA, NIGERIA

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ABSTRACT

The physico-chemical properties of soils regulate nutrients supplied to plants. Their importance in nutrient supply to crops has to be continuously monitored to achieve optimum production of crops for sustainable development. This study aim to examine the physico-chemical properties of soils under vegetable cultivation in Abuja metropolitan area. Soil was sampled from five farmlands and one fallow land at different locations within the city. At each location, a quadrant of 15m by 12m was first demarcated and five soil samples were randomly selected. Composite surface (0-10cm) soil samples were taken over each sub-quadrant and analysed using standard methods. Quantitative data obtained from routine chemical analysis were subjected to statistical analysis. The results revealed that soil parameters showed significant variations among the different locations, except for available phosphorus. Texturally, the soils vary from sandy clay loam, sandy loam to sandy clay. Soil pH was slightly acidic to neutral (6.2-6.7), while organic matter and available phosphorous was low. Exchangeable Ca was rated medium, Mg and Na were rated medium to high while K was rated low to medium. Cation exchange capacity (5.78-8.18 cmol/kg) and % base saturation (69-82%) *were medium. The soils were low in fertility and need the adoption of proper management practices in terms of organic and inorganic fertilizer application to resuscitate and sustain the soil fertility. Adequate monitoring of fertility status of the farm should also be carried out at regular intervals for sustainable production.*

Keywords: Abuja, Physico-chemical properties, Soils, Vegetables.

INTRODUCTION

Soil is a component of the terrestrial ecosystem that performs many functions including those that are essential for sustaining plant growth (Paudel and Sah, 2003). The importance of soil as a reservoir of nutrients and moisture for the production of forage and plant species makes soil a very vital natural resource. The soil's physical, chemical and biological properties affect plant growth. Properties of a soil largely determine the ways in which it can be used. Physico-chemical characteristics of different soils vary in space and time due to variation in topography, climate, physical weathering processes, vegetation cover, microbial activities and several other biotic and abiotic variables (Nwachokor, Uzu and Molindo, 2009).

The proportions of four major components of soils, inorganic particles, organic materials, water and air can vary greatly from place to place and with depth (Esu, 2010). The amount of water and air in a soil can also fluctuate widely from season to season. Chemical properties of soils are important in that, along with their physical and biological properties, they regulate nutrient supplies to the plant. Without these nutrients supplied by soil or applied as inorganic fertilizers; organically by manures, and other vegetative materials, plant growth would cease (Haby *et al.*, 2009). The biological properties of soil are dictated by macro-organisms and micro-organisms. Optimum physical and chemical properties supply the right environment and sufficient nutrients to organisms for optimal biological activity. This, in turn, improves soil physical and chemical properties through improved structure and nutrient cycling (Haby *et al.*, 2009). Optimum plant growth and crop yield depends not only on total amount of nutrients present in the soil at a particular time but also on their availability which in turn is controlled by physico-chemical properties like soil texture, organic carbon and calcium carbonate, cation exchange capacity, pH and electrical conductivity of soil (Bell and Dell, 2008; Jimoh *et al.*, 2015).

Vegetables are an important component of a healthy diet in the world (Obuobie *et al*., 2006). If consumed daily in sufficient amounts, they would help prevent major diseases such as cardio-vascular diseases and certain cancers. There are 20 essential chemical elements (plant nutrients) known to be required for normal vegetable growth. These elements can be supplied by either organic or commercial inorganic fertilizers. Carbon, hydrogen, and oxygen from air and water and nitrogen from organic and inorganic sources are four plant nutrients which make up 95% of plant solids. Although the atmospheres consist of 78% nitrogen as N_2, this form is unavailable for plant use. However, certain bacteria that live symbiotically in nodules on the roots of legumes are able to take nitrogen from the air and fix it in a form available to plants (Haby *et al.*, 2009). Agbenin and Goladi (1997) reported a rapid decline of organic matter, followed by extensive leaching of basic cations (examples, potassium, magnesium and calcium) and rapid development of acidity when most savanna soils undergo continuous cultivation. Continuous and unguided use of soils has greatly reduced land capacity to feed mankind, especially in the tropics, which have resulted to declining soil productivity as recently being experienced by farmers resulting to low crop yield in Abuja metropolitan area (Suleiman, 2014). The decline in soil productivity is believed to be a resultant effect of declining soil quality. This necessitated this study to assess physico-chemical properties of soils, especially as they relate to fertility, is a pre-requisite for efficient use of soil resources (Khan *et al.*, 1998; Mustapha *et al.,* 2001). A good understanding of soil physical and chemical properties is essential for determining suitability of soils for different agricultural practices and as such, this study aim to examine the physico-chemical properties of soils used for vegetable cropping in Abuja metropolitan area.

THE STUDY AREA

The study area lies in the northeastern part of the Federal Capital Territory (FCT) and occupies some 250 km^2 (Fig. 1). The area is characterized by a hilly, dissected terrain and is the highest part of FCT with several peaks that are 760m above sea level (Balogun, 2001). The study lies between Latitudes 8.25^0 N and 9.20^0 N and Longitudes 6.45^0 E and 7.39^0 E. The rainfall is largely influenced by the Inter-Tropical Convergence Zone (ITCZ). Consequently, there is a distinct rainy season that starts in April and ends in October and a dry, cold season that begins in November and ends in March. The area also enjoys a rainy season of about 170 days on the average. The temperature ranges from 25.8^{0}C to 35.2^{0}C while the relative humidity ranges over 50% in raining season to 20% during the dry season (Balogun, 2001).

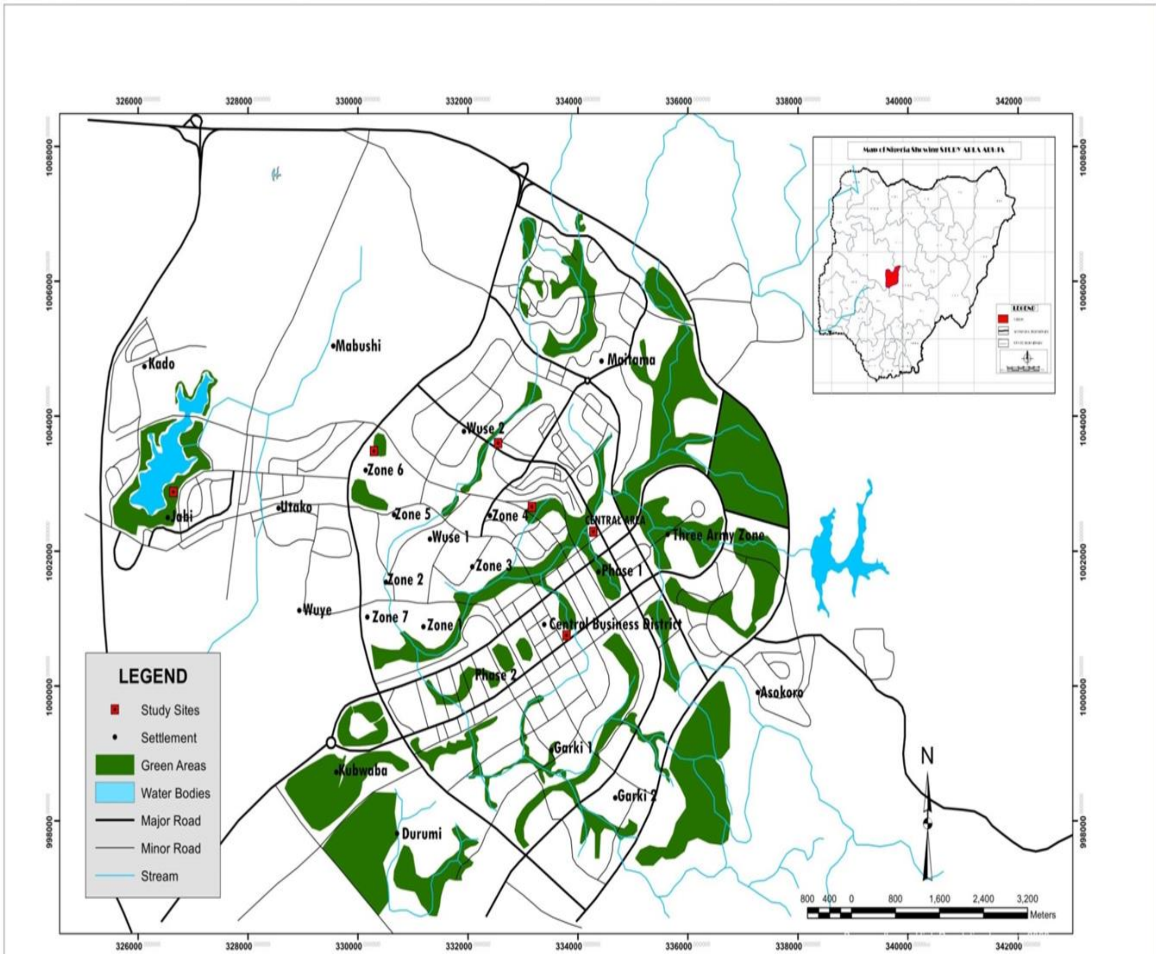

Figure 1: Abuja metropolitan area showing the study sites
Source: Digitized from google earth imagery

The area is underlain by Precambrian Basement Complex rocks and consists mainly of gneisses and schist with migmatite, granites and small occurrences of quartzite, pegmatite, amphiboles, granitic gneisses and diorites. The entire Gwagwa Plains on which entire FCT is located belong to the basin of Usuma River, which rises in Bwari-Aso Hills to the northeast, flows first westwards and then south-westwards onto Iku-Gurara plains. In general, the drainage pattern is dendritic to rectangular pattern. Most soils in the area are ferruginous tropical soils. Others include the lithosols and alluvial soils. The vegetation is thick woodland or dry forest. Evidence of such vegetation still exists in few reserves areas within or around the city. Example of some of the species are; *Daniellia oliveri*, *Khaya senegalensis*, *Mangifera indica,* and *Dalbergia sissoo* (Suleiman, 2014).

MATERIALS AND METHODS

Selection of Plots

A reconnaissance survey of Abuja Metropolitan Area was carried out as a base for data collection. Five plots under urban cropping and a fallow land which serve as control were selected for the study, making a total of six plots.

Soil Sampling

A combination of systematic and random sampling method was used for sampling each plot selected for study; a quadrant of 15m by 12m was first demarcated. Each was subsequently subdivided into 20 sub-quadrants measuring 3m by 3m from which 5 areas were randomly selected for soil sampling. Five soil samples were taken at the four corners and the centre of each selected sub-quadrant. The samples were bulked to give a composite sample per sub-quadrant; hence five (5) bulked samples per plot, giving a total of 30 soil samples collected for laboratory analysis.

Laboratory Analysis

The composite soil samples from each plot were air-dried, crushed lightly, and then passed through a 2mm sieve. The <2mm fraction were used for soil physical and chemical analyses. Particle size distribution was determined by the hydrometer method (Gee and Bauder, 1979). Soil pH was measured in water and 0.1M $CaCl_2$ at a ratio of 1:2.5 w/v using glass electrode pH meter (Agbenin, 1995). Organic carbon was determined by the dichromate wet oxidation method of Walkley and Black (Nelson and Sommers, 1982). Cation exchange capacity (CEC) was determined using the ammonium acetate method (Agbenin, 1995). Base saturation was calculated as the sum of total exchangeable bases divided by cation exchange capacity (NH_4OAc) (Agbenin, 1995). Available P was determined using Bray 1 method (IITA, 1979). Exchangeable bases (calcium, magnesium, potassium and sodium) in the soil were determined using the ammonium acetate extract from the CEC determination. Sodium and K were determined using flame photometer while Ca and Mg was determined using atomic absorption spectrometer. The soil was analysed at the Institute for Agricultural Research (IAR), Ahmadu Bello University, Zaria. The results obtained were subjected to statistical analysis using Analysis of Variance (ANOVA). The means were separated using Duncan Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Soil Physical Properties

Soil Textural Distribution

Table 1 indicates that sand which dominates inorganic fraction of the soil was significantly different ($p> 0.05$) in mean values amongst the different location. Jabi lake and Wuse zone 2 were significantly higher than Wuse zone 1, Central area and National mosque site but didn't differ significantly from fallow land (Wuse zone 6). Silt content also varies significantly ($p> 0.05$). National mosque sample site was significantly higher than other sites, with the fallow land (Wuse zone 6) recording least value (157 mg/kg). This implies that silt fraction is more uneven within each location. Similar to the sand content, clay content shows significant difference (p>0.001) in mean values amongst the various locations. Wuse zone 1 and Central area were statistically similar but they were significantly higher than other locations while Jabi lake recorded the least value. Generally, soil texture ranges from sandy clay loam, loamy sand and sandy loam, which implies all groups of soils are sandy which may be mainly due to the coarse-textured nature of the parent rock over which the soils were formed (Jaiyeoba, 1986).

Table 1: Mean variation of soil texture over different studied sites.

Location	Sand	Silt	Clay
Wuse-Zone 1	576.40b	173.60b	250.00ab
Central Area	566.00b	165.00b	269.00a
Jabi Lake	766.00a	308.40b	74.00e
National Mosque	537.70b	308.40a	154.00cd
Wuse- Zone 2	720.00a	174.00b	106.00de
Wuse-Zone 6	637.00ab	157.00b	206.00bc
SE±	12.96	11.00	2.27

Means with the same letter in a column are not significantly different at 5 % level of probability using Duncan multiple range test.

Other factors that could account for the sandy nature of the soils could be the elluviation of finer particles from the top horizon and illuviation in the lower horizon and also, the selective removal of finer particles in wash processes (Jaiyeoba, 1986; Sharu *et al.*, 2013; Jimoh, 2015).

Soil Chemical Properties

Soil pH, Organic carbon and Available P

The soil pH was slightly acidic to neutral (6.18–6.74) which is the pH requirement for most arable crops for nutrient uptake (Brady and Weil, 1999). Soil pH varies significantly (p>0.001) over different locations. Wuse zone 2 was significantly higher than other sites with Jabi lake recording least value (Table 2). The soil organic carbon range of 6.12 - 9.10 g/kg was rated low (Malgwi, 2007). Soil organic matter is known for its high influence on soil physical and chemical properties (Agbede, 2009).

Table 2: Mean variation of soil chemical properties over different studied sites.

Location	pH	OC	Ap
Wuse-Zone 1	6.34c	9.10a	5.2a
Central Area	6.32c	7.34ab	2.4a
Jabi Lake	6.18d	5.34b	4.3a
National Mosque	6.58b	8.44ab	5.2a
Wuse Zone 2	6.74a	6.12ab	4.6a
Wuse-Zone 6	6.28cd	8.38ab	4.8a
SE±	0.00	0.30	6.20

Means with the same letter in a column are not significantly different at 5 % level of probability using Duncan multiple range test.

Soil organic matter contributes greatly to soil N, P, S, CEC and exchangeable cations. Where organic matter is lacking, these soil properties will be adversely affected. Greenland (1994) identified soil organic matter as the most important property in sustainable soil productivity. There was significant difference ($p>0.05$) in organic carbon amongst the different sites. Wuse zone 1 was significantly higher in organic carbon than Jabi lake but similar to the other site including the fallow land. The low mean value of organic carbon content is a reflection of intensive anthropogenic influence such as continuous cultivation and bush burning (Young, 1976; Jaiyeoba, 1988; Yakubu, 2001), and intensive use of these soils for continuous cultivation and the rapid mineralization of humus under savanna climate. The mean values of Available P was rated low and there was no significant difference amongst the various sites. It varied from 2.30 mg/kg to 5.20 mg/kg. The comparatively low Available P over the different sites is a reflection of the low organic carbon content. This is because Available P and Organic Carbon occur in organic combination and therefore, a reduction in one would lead to the reduction in the other and vice versa (Brady and Weil, 1999).

Exchangeable cations (Calcium, Magnesium, Potassium and Sodium)

The value of exchangeable Ca (2.98-4.89 cmol/kg) was rated medium. The values were relatively similar over the sites; with the exception of Wuse zone 1 having the highest value of 4.86 cmol/kg. This implies an uneven distribution of exchangeable Ca within the plots. Wuse zone 1 was significantly higher than other locations with Jabi lake recording the least value (Table 3).

Table 3: Mean variation of soil chemical properties over different studied sites.

Location	Ca	Mg	K	Na
Wuse-Zone 1	4.86a	0.88ab	0.18ab	0.36ab
Central Area	3.42b	0.74b	0.15ab	0.31a
Jabi Lake	2.98b	0.74b	0.05c	0.20b
National Mosque	3.82b	1.14a	0.19ab	0.42a
Wuse Zone 2	3.82b	1.15a	0.21a	0.34ab
Wuse-Zone 6	3.64b	0.81ab	0.11ab	0.46a
SE±	0.08	0.03	0.01	0.02

Means with the same letter in a column are not significantly different at 5 % level of probability using Duncan multiple range test.

Magnesium values of (0.74-1.15 cmol/kg) were rated medium to high. The values differed significantly ($p>0.01$) across the locations. National mosque and Wuse zone 2 were statistically similar and higher than other sites. Except for Central area and Jabi lake which were significantly different from National mosque and Wuse zone 2. Exchangeable K values (0.05-0.21 cmol/kg) were rated low to medium and reveal significant differences (0.01) amongst the different sites. Wuse 2 was statistically similar to other sites, except for Jabi lake which was significantly different from Wuse zone 2. Exchangeable Na values of (0.20-0.46 cmol/kg) were rated medium to high. Fallow land (Wuse zone 6) recorded the highest value though statistically similar to other location; except Jabi lake, which was statistically different from Wuse zone 6. Overall, the relatively low values of exchangeable cations may be a reflection of losses through either cultivation, harvesting or leaching (Wilson and Kent, 1983). This phenomenon could also be as a result of greater mobilization by plants or greater weathering and release of the elements within the soil (Fitzpatrick, 1980).

Cation exchange capacity (CEC) and Base saturation

Cation exchange capacity (CEC) help to evaluate soil fertility, as it determines the capacity of a soil to hold nutrients and eventually release them for plant uptake. The soil CEC values of (5.78-8.18 cmol/kg) were rated medium (Table 4). These show considerable variability over the different sites. The value is lowest over Jabi lake (5.78 cmol/kg) and highest over Wuse zone 1 (8.18 cmol/kg) while those over Central area (6.66 cmol/kg) and Fallow land (Wuse zone 6) (7.02 cmol/kg) are intermediate.

Table 4: Mean variation of soil chemical properties over different studied sites.

Location	CEC	BS
Wuse-Zone 1	8.18a	76.68ab
Central Area	6.66ab	69.83bc
Jabi Lake	5.78c	67.83c
National Mosque	6.68bc	83.49a
Wuse Zone 2	6.84a	80.74a
Wuse-Zone 6	7.02b	71.60c
SE±	0.10	0.45

Means with the same letter in a column are not significantly different at 5 % level of probability using Duncan multiple range test.

Analysis of variance thus shows highly statistical difference amongst the various sites ($p>0.05$). Wuse zone 1 recorded the highest CEC value and was statistically similar to Central area and Wuse zone 2 but was significantly higher than Jabi lake which recorded the least value (Table 4). The comparatively medium CEC values of the various plots reflect lower organic carbon content of the different sites or it may be that clay mineralogy of the soil is predominantly chemically less active Kaolinite type (Fitzpatrick, 1980; Hamdan *et al.*, 1998). Base saturation (NH_4OAc) of surface soils were rated medium (67.8 – 83.5 %) in all the areas, similar to result of Jimoh *et al.* (2016) who also reported medium level of base saturation in soil of Gabari district, Zaria. The Food and Agricultural Organisation (FAO) (1999) reported that soils with base saturation of >50 % are regarded as fertile soils while soils with less <50 % were regarded as none fertile soils. Results of soil properties determined in this investigation confirm the domineering influence of lithology and anthropogenic factors in tropical soil formation.

Fertility Implications of Soils of Abuja Metropolitan Area for Vegetable Cultivation

The fertility of a soil is determined by soil physical and chemical properties that is its nutrient reserves. Texture is an important factor to consider when determining suitability of soil for vegetable farming. Root penetration, nutrition absorption, water holding capacity, water infiltration and percolation are affected by soil textural type (Sys *et al.*, 1991). According to Aliyu (2016), loam and sandy loam are much more preferred soil texture for vegetable farming.

The soils of the study area were dominated by loam and sandy loam textural class, thus optimum for vegetable production.

The pH value of all the soil falls within the normal range of 5.5-7.0, values reported being optimum for the release of plant nutrients (Sharu *et al.*, 2013), thus suitable for vegetable production. Cation exchange capacity of soils of the study area was medium, this implies that these soils have the capacity to store and readily supply nutrient to the vegetables. The values of BS are rated medium to high, this means that the soil has high nutrient retention capacities. Exchangeable bases concentration shown in Table 3 of the soils were rated medium to high, this indicates that these exchangeable bases are optimum for vegetable production except exchangeable potassium which was rated low to medium, thus addition of fertilizer rich in potassium will be required. Organic carbon and Available phosphorus content of the soil as indicated in Table 2 is low, this infers that this nutrient will not sustain the production of vegetables in the study area. The incorporation of organic residues will increase nutrient retention capacities, improve soil aeration, drainage, structural development, reduce erosion and reduce leaching (Maniyunda, 1999). Organic carbon had been reported by many authors (Jimoh, 2015; Aliyu *et al.,* 2016), to correlate with total nitrogen, available phosphorus, cation exchange capacity and micronutrients, thus indicating that organic carbon was the main source of these nutrients (Kebeney *et al.,* 2015). Therefore, farmers should incorporate cattle dung, poultry droppings and other organic materials while overgrazing and bush burning should be discouraged.

CONCLUSION

The study examined physical and chemical properties of soils used for vegetable cultivation in Abuja metropolitan area. Results obtained show that texture of the soils is generally sandy loam. All the locations show significant variation for sand, silt and clay. The organic matter and available P content of soils is generally low over the study area. The exchangeable cations depict relatively medium values throughout the sites. The values of soil pH also showed significant differences amongst the different sites, so is the CEC and base saturation. Generally, the fallow land (Wuse zone 6) which was used as control did not reveal any significant difference from the other site.

It was recommended that organic residues should be incorporated into the soil which will increase nutrient retention capacities, improve soil aeration, drainage, structural development, improve pH and reduce leaching for vegetable production. Application of mineral fertilizer nutrients; especially P and K which are present in low concentration is necessary so as to increase the yield of vegetable. Adequate monitoring of fertility status of farm should be carried out at regular intervals for sustainable vegetable production.

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