# CHARACTERIZATION, CLASSIFICATION AND SUSTAINABILITY STATUS OF AGRICULTURAL SOILS OF ABAJI AREA COUNCIL IN THE FCT, NIGERIA

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**Abstract**

*A study was carried out to characterize the agricultural soils of Abaji and to evaluate their sustainability status. Two agricultural estates were picked in in the area. A profile pit was dug in each estate and were studied morphologically. Samples were collected, prepared and analysed in the laboratory following standard procedures. The results showed the soils were deep ranging from 163 – 216 cm. Soil colour in the Abaji area are predominantly red with hues of 2.5YR, 5YR, 7.5YR and 10R. The soils were sandy loam, sandy clay loam and clay loam in texture. Most of the epipedons had moderate and medium crumb structure, while the endopedons had moderate medium sub angular blocky structure. Soil pH ranged from slightly acidic to neutral (6.3 – 6.7). Electrical conductivity in all the soils was low, organic carbon and total nitrogen were low and moderate and had regular distribution pattern within the profiles. Exchangeable cations were low and Cation exchange capacity was low to moderate. The soils of Abaji were classified based on USDA Soil Taxonomy as Kandic Rhodustalf which correlates with Rhodic Lixisol Dystric in WRB. In terms of sustainability status, the two soil units of Abaji were sustainable under the current land use. The soils were considered to be of low to moderate fertility and would require integrated nutrient management approach in ensuring optimum productivity level.*

**Key words:** Agricultural soils, Characterization, Classification, Sustainability Status, Abaji.

## INTRODUCTION

The science of classifying soils over the years has helped in organizing knowledge about our soils and appropriating management recommendations for optimum productivity and yield of crops (Barnabas and Nwaka, 2014). According to Iyanam et al (2024), Soil characterization, classification and mapping provide a powerful resource for the benefit of mankind, especially in the area of food security and environmental sustainability. The sustainable development goals (SDG) 1 and 2 have emphasized the need for poverty eradication and sustainable food security for all. These goals are achievable, only if our soils are managed adequately and sustainably. The key therefore to sustainable management and utilization of our soil resource is classifying the soils (Weil and Brady, 2016).

Our soils are not only fragile, but are very dynamic, they respond to influences of management and utilization over time. Basic soil resources information is a veritable tool for sustainable management of our fragile and scarce soil resource, in a bid to ensure optimal productivity of our soils and their ability to remain productive for future use (Ogwueleka *et al*, 2023).

According to the revised World Soil Charter (FAO, 2015) soil management is sustainable if the supporting, provisioning, regulating, and cultural services provided by soil are maintained or enhanced without significantly impairing the soil functions that enable those services or biodiversity. The Status of the World's Soil Resources Report identified ten threats that hamper the achievement of sustainable soil management (SSM). These threats are: soil erosion by water and wind, soil organic carbon loss, soil nutrient imbalance, soil salinization, soil contamination, acidification, loss of soil biodiversity, soil sealing, soil compaction and waterlogging (Soil Survey Staff, 2022). These different threats vary in terms of intensity and trend depending on geographical contexts, though they all need to be addressed in order to achieve sustainable soil management (FAO and ITPS, 2015). Agricultural estates within Abuja have remained major contributors to food production and supply in Abuja and surrounding states. It is therefore imperative that we classify the soils and appropriate management recommendations based on sustainability status of the soils.

**Materials and Methods**

Study was carried out in Abaji, Area Council of the Federal Capital Territory. The FCT is located in the Southern Guinea Savanna between longitudes 6° 20'E and 7° 33'E and latitudes 8° 30'N and 9° 20'N and occupies an area of about 8,000 $km^2$ (FCDA, 2019). The area is characterized by two distinct seasons, the dry and wet seasons. The rains last from May to October with its peak in August and September having mean annual rainfall of 1300 mm. (Zubair *et al*., 2015).

**Field Procedures**

Two profile pits were dug in each of the selected Area council and was described morphologically. Soil samples were collected according to pedogenic horizons and labelled accordingly. Samples were prepared and sent to laboratory for analysis.

**Laboratory Procedure**

Samples for bulk density were weighed immediately before oven drying and weighed again. Particle size distribution was determined using the wet hydrometer method of Bouyoucous (Udo *et al*., 2009), saturated hydraulic conductivity was determined using fall head method (Hilel, 1980, Soil aggregate stability was determined by the wet sieving method (Hillel, 1980). mean weight diameter was achieved through calculation (Obi, 2000). Soil pH and electrical conductivity were determined by electrometric method using pH meter and EC meter (IITA, 2015). Organic carbon was determined by the modified Walkley – Black method as described by Nelson and Summers (1982). Total nitrogen was determined by the macro-Kjeldahl digestion and distillation procedures as described by IITA (2015). Available phosphorous was determined by using Sodium bicarbonate {$Na (HCO_3)_2$} extracting solution (Olsen and Dean, 1965). Exchangeable Cations and Percentage base saturation was determined by ammonium acetate extraction method as described by IITA (2015). Cation Exchange Capacity (CEC) was determined by neutral 1N ammonium acetate method (Udo *et al*., 2009).

**Soil Classification**

The soils were classified using USDA Taxonomic Classification system as outlined in Soil Survey Staff (2022), as well as their correlation in the IUSS Working Group WRB (2022).

**Sustainability Assessment**

The sustainability of the soil health values was assessed to know if the current soil health can be sustained by the current land use. The critical level according to Lal 1994 was used to assign relative weighting factors to the selected indicators. The limitation ranges with relative weighting factors of 1 to 5 will also be used as follows in tables 1 and 2.

Table 1: Limitation rates for Sustainability Assessment

| Weighting factor | Limitation | Remarks |
|---|---|---|
| 1 | No limitation | the negative effect of the indicator on sustainability of land use is nil |
| 2 | Slight limitation | the negative effect of the indicator on the sustainability of land use is slight |
| 3 | Moderate limitation | the negative effect of the indicator on sustainability of land use is moderate |
| 4 | Severe limitation | the negative effect of the indicator on sustainability of land use is severe |
| 5 | Extreme limitation | the negative effect of the indicator on sustainability of land use is extreme |

Source: Lal (1994)

Table 2: Sustainability rating

| Sustainability ratings | Cumulative Rating Index |
|---|---|
| Highly sustainable | <20 |
| Sustainable | 20 - 25 |
| Sustainable with high input | 25 - 30 |
| Sustainable with another land use | 30 - 40 |
| Unsustainable | >40 |

Sources: Lal (1994)

**Results and Discussion**

**Soil depth and horizonation**

The results of morphological properties of soils are presented in Table 3. Soils of the Federal capital territory were moderately deep to very deep with effective profile depths ranging from 163 – 216 cm deep. In terms of horizonation, the soils of Abaji had well developed horizons with the A horizons being influenced by ploughing/cultivation hence identified as Ap epipedons. The soils had well developed B horizons indicating presence of argillic horizons with sub-designations of Bt1 – Bt3. Transitional horizons between B and C (BC) horizons were observed with significant evidence of argillic property and partial weathering of parent materials.

The agricultural soils of the Federal capital territory Abuja are deep. This was also reported by Barnabas and Nwaka (2014). The deep status of the soils also satisfies most tree crops establishment by providing adequate environment for plants roots' growth and development. Ahmad *et al*. (2020) also reported that the deep soils provides opportunity for good water infiltration especially where there is no lithologic discontinuity within the soil solum. The result is also consistent with the report of Aki *et al* (2017), and Osuijieke, *et al*. (2017).

**Soil colour**

The colour of the soils of Agena in Abaji area council had a hue that ranges from 2.5 YR to 7.5 YR and 10 R. In the soils of Nuku, the dominant matrix was a hue of 5 YR. The surface horizon had a dark brown colour with a value of 4 and a chroma of 4. In the subsurface horizons, the soil colour varied from yellowish red to reddish yellow and Red with a hue of 10R and a value of 4. The chroma was 6. In the soils of Nuku, the dominant matrix colour had a hue of 5YR. Colour description for the surface soil was dark reddish brown while in the sub surface soil, the colour was described as reddish yellow. In general, the soils of Abaji were rhodic in appearance as determined under dry condition using the Munsell Colour Chart.

The reddish colouration of the soils could be attributed to mineralogical composition of the parent materials which are believed to be chiefly comprised of hematite and goethite which have high iron oxides. These soils may contain large amount of clay and are derived principally from the weathering of ancient crystalline and metamorphic rocks. These assertions agree with the reports of Asadu and Ezike (2017) and Lawal *et al*. (2012). The results of soil colour as observed here could be attributed to factors such as mineralogical composition of parent materials, drainage condition and other environmental factors as also reported by other researchers such as Osujieke, *et al*. 2018), Asadu and Ezike (2017) and Osujieke *et al* (2016). However, the dark colour tinge in the surface horizons may be as a result of organic matter deposit. It is clear also from literatures that many soils are brown in colour because they contain large amounts of carbon. Especially, carbon polymers called humic compounds absorb most visible wavelengths of light and give soils a dark brown appearance (Usman *et al*, 2017; Weil and Brady, 2016).

**Soil structure and consistence**

Soil structure at the Ap horizon soils of Abaji Area council was weak fine crumb structure across the two locations studied (Agena and Nuku). In the subsurface horizons, the structure ranged from moderate medium sub angular blocky, moderate medium blocky, strong moderate subangular blocky and strong moderate angular blocky. Soil consistence was determined and estimated at three moisture conditions: wet moist and dry. Soil consistence at the Ap horizon of Agena and Nuku soils were non plastic and non-sticky in wet condition, friable when moist and soft when dry. In the sub surface horizons, soil consistence under wet condition was slightly sticky and slightly plastic, sticky and plastic and very sticky and very plastic. In the moist state, the soils were firm, and very firm while in the dry state the soils were hard and very hard.

**Soil Physical Properties**

The result of physical properties of the soils of the Federal Capital Territory Abuja are shown in Table 3

**Particle size distribution**

The result showed that for Agena soil unit, sand fraction within the profile ranged from 430 – 674 g $kg^{-1}$. Silt fractions within the profile ranged from 120 – 240 g $kg^{-1}$, while clay fractions ranged from 186 – 337 g $kg^{-1}$. For the soils of Nuku, sand fraction in the sub soil ranged from 447 – 676 g $kg^{-1}$ while silt fraction ranged from 122 – 250 g $kg^{-1}$. The clay content within the profile ranged from 182 – 303 g $kg^{-1}$. The sand content was high and decreased with increasing profile depth. Silt content was moderate while clay was low in the surface soils but increase with increase in soil profile depth. This finding agrees with Madueke *et al* (2012) and Osujeike *et al* (2018) who observed that high values of silt content is an indication of low weathering status and formation of young soils. The high sand content of the soils could be attributed to nature or type of parent material from which the soils were formed. This agrees with the reports of Osujeike *et al* (2018), Obasi *et al* (2016) and Barnabas and Nwaka (2014) that parent materials influences soil texture. The major parent materials observed across the study sites included basalts and schists. Silt/clay ratio is considered an important indicator in assessing the extent of weathering of parent materials and clay migration within a profile as reported by Nwaka (1990), Yakubu and Ojanuga (2013) and Barnabas and Nwaka (2014). The soils of the study area had a silt/clay ratio that is classified as moderate indicating that the soils are relatively young with a high degree of weathering potential.

Bulk density of the soils at the s surface horizons across the FCT ranged from 1.30 – 1.35 $gcm^{-1}$ and that would not constitute impediment to root growth and development within the soils. However, the results also indicated that bulk density in all the soils was higher at the subsurface horizon. The higher values of bulk density in the subsurface soils can be attributed to weight of overlying horizons as also reported by Usman *et al*, (2018). Higher bulk density may exert significant influence on the rate of water infiltration, roots growth and development, and ease with which the soils could be worked as opined by Weil and Brady (2016). The soil total porosity reflects an inverse pattern with the bulk density as low bulk density in soils implies high total porosity. The moderate to high porosity of the soils suggests that the macro and micro pores of the soils are open to allow free movement of air and water into the soil for the effective performance of plants' roots in the soil. Saturated hydraulic conductivity of the soils was higher at the surface horizons and decreased down the profile. This was attributed to higher sand content of the surface horizons and lower bulk density that allows easy and free rapid flow of water into and through the soil as noted by Landon (1991).

**Chemical properties of the soils of Abuja**

The chemical properties of the soils of Abuja are presented in Table 4

**Soil pH**

Soil pH of the surface horizon of Agena soils as determined in $H_2O$ was 6.2 (slightly acidic) while in KCL, the pH was 5.60. Within the profile however, pH in $H_2O$ ranged from 6.2 – 6.3 (slightly acidic) while for pH in KCl the values ranged from 5.4 – 5.6. At the surface horizon of Nuku, pH in $H_2O$ was 6.3 (slightly acidic) and 5.4 in KCl. Within the profile depth, pH in $H_2O$ ranged from 6.2 – 6.5 (slightly acidic). In KCl, the pH values ranged from 5.5 – 5.6.

According to the ratings of Chude *et al*, (2011), the soils of Abaji were slightly acidic to neutral. Weil and Brady (2016) attributed acidic soils to the acidic nature of parent materials from which the soils are derived. Wapa *et al* (2017) also attributed pH of soils in an area to the nature of parent materials, climatic regime of the area, organic matter in the soils and topographic position of the soils. In this study, the basaltic parent material in the area could have accounted for the neutral pH status of the soils in the two locations studied because of their basic nature

**Soil electrical conductivity (EC)**

Electrical conductivity at the surface horizon of Agena soils was 0.13 dS $cm^{-1}$. Within the profile depth however EC ranged from 0.11 – 0.14 dS $cm^{-1}$. The distribution of EC in the soils of Agena did not follow any definite trend within the profile depth. At the surface horizon of Nuku, EC was 0.13 dS $cm^{-1}$ while within the profile depth, EC ranged from 0.10 – 0.13 dS $cm^{-1}$. Also, the trend of occurrence did not show any definite pattern of distribution within the profile. Generally, EC was low and below the critical limit for agricultural soils

Electrical conductivity values were very low in all the areas studied with values at both surface and subsurface horizons across the locations being lower than the critical value of 0.45 dS $cm^{1}$ for safe agricultural soils (Chude *et al*., 2011).

**Organic carbon (OC)**

Organic carbon (OC) in the surface horizon of Agena soils was low and had a value of 1.11 g $kg^{-1}$. Within the profile depth, OC ranged from 1.10 – 2.98 g $kg^{-1}$. For the soils of Nuku area in Abaji, soil organic carbon at the surface horizon of the soil was 2.97 g $kg^{-1}$ while within the profile depth, SOC ranged from 0.93 – 2.96 g $kg^{-1}$. The results showed that organic matter was higher in the surface horizons and lower in the profile subsurface horizons. This trend could be attributed to nutrient bio cycling and eluviation of materials from upper to lower horizons within the soil profiles as also reported by Idoga and Azagaku (2005) and Gisilanbe *et al* (2019). High organic carbon content of the surface horizons can be attributed to litter fall and increase in soil biodiversity as suggested by Adepetu *et al* (2014), also because the surface horizon is the site where all forms of biochemical processes takes place. The surface horizon tends to have more population of microfaunas and floras as a result of organic matter decomposition. Also, Osujieke *et al* (2018) opined that cultural practices by farmers and effects of erosion and deposition affect organic carbon distribution. Soil texture has a strong influence on soils ability to store organic carbon (Weil and Brady, 2016) but its distribution reflects a combination of soil physical properties, biomass input as well as decomposition rates which are functions of climatic condition prevalent in the region. High organic carbon translates into high organic matter in the soil and this is possible because about 58 % of organic matter in the soil exist in the form of carbon as stated by Landon (1991) and (Adepetu *et al* (2014).

**Total Nitrogen**

At the surface horizon of Agena in Abaji, soil total nitrogen (TN) was 0.10 g kg$^{-1}$ while within the profile, TN ranged from 0.08 – 0.10 g kg$^{-1}$. At the surface horizon of Nuku, TN was 0.09 g kg$^{-1}$ while within the profile, TN ranged from 0.05 – 0.10 g kg$^{-1}$. The status of TN was low in all the soils. Total nitrogen in the soil was low to moderate and reflects the trend of organic carbon in the soil. This is because organic carbon/organic matter serves as the store house of plant nutrients in the soils. Sanni (2012), Barnabas and Nwaka (2014) and Osujieke *et al* (2017) reported similar trends.

**Available Phosphorus**

Available phosphorus (AP) at the surface horizon of Agena was 9.96 mg kg$^{-1}$ while within the profile, AP ranged from 6.25 – 10.83 mg kg$^{-1}$. At the surface horizon of Nuku profile, AP was 16.67 mg kg$^{-1}$ while within the profile depth, AP ranged from 15.42 – 20.00 mg kg$^{-1}$. The distribution of AP within the profiles did not follow any definite pattern of occurrence, however, AP was relatively higher in the Nuku soils than the soils of Agena.

Soil available phosphorus was moderately high in the surface horizons of soils across the different sites studied and decreased with increase in soil depth. The high available P in the soil is attributed to the soil pH being generally slightly acidic to near neutral, as this pH range favours the availability of phosphorus in the soil. The concentration of available P closely followed the organic carbon distribution in the soil. Onyekwere *et al* (2020) and Mohammed *et al* (2024) reported a high positive correlation of N and P with organic carbon in soils of South eastern Nigeria and southern Guinea Savanna respectively.

**Exchangeable cations (Ca, Mg, K, Na & EA)**

Calcium in the surface horizon of Agena soils was 6.70 cmol kg$^{-1}$ and within the profile the Ca in the soil ranged from 3.91 – 7.41 cmol kg$^{-1}$. In the soils of Nuku Ca in the surface horizon was 4.33 cmol kg$^{-1}$ while within the profile depth, Ca ranged from 5.36 – 6.22 cmol kg$^{-1}$. Magnesium at the surface horizon of Agena was 4.33 cmol kg$^{-1}$ while within the profile depth, Mg ranged from 2.11 – 3.96 cmol kg$^{-1}$. At the surface horizon of Nuku, magnesium was 2.91 cmol kg$^{-1}$ while within the profile depth Mg ranged from 1.36 – 4.21 cmol kg$^{-1}$. Exchangeable potassium at the surface horizon of Agena soil was 0.18 cmol kg$^{-1}$ while within the profile, K ranged from 0.10 – 0.27 cmol kg$^{-1}$. At the surface horizon of Nuku, potassium was o.13 cmol kg$^{-1}$ while within the profile, K ranged from 0.08 – 0.17 cmol kg$^{-1}$. Sodium at the surface horizon of the Agena soil was 0.03 cmol kg$^{-1}$ while within the profile depth, Na ranged from 0.03 – 0.06 cmol kg$^{-1}$. At the surface horizon of Nuku, Na was 0.06 cmol kg$^{-1}$ while within the profile, Na ranged from 0.03 – 0.09 cmol kg$^{-1}$. Exchange acidity at the surface horizon of Agena was 1.08 cmol kg$^{-1}$ while within the profile depth, exchangeable acidity ranged from 0.84 – 1.20 cmol kg$^{-1}$. At the surface horizon of Nuku soil, exchangeable acidity was 0.84 cmol kg$^{-1}$ while within the profile depth, exchangeable acidity ranged from 0.96 – 1.08 cmol kg$^{-1}$.

Soil exchangeable cations in the soil were low and the total exchangeable bases showed that calcium (Ca) and magnesium (Mg) are the most predominant basic cations in the soils of the area. Osujeike *et al* (2018) reported similar findings.

**Cation exchange capacity (CEC)**

Cation exchange capacity at the surface horizon of Agena soil profile was 12.7 cmol kg$^{-1}$ while within the profile depth in the subsurface horizons, the CEC ranged from 7.89 – 10.98 cmol kg$^{-1}$. The trend of occurrence here showed that CEC was higher at the surface horizon bub decreased in the lower horizons. For the soils of Nuku, CEC at the surface horizon was 8.88 cmol kg$^{-1}$ while within the profile depth, CEC ranged from 10.90 – 12.29 cmol kg$^{-1}$.

Cation exchange capacity (CEC) of the soils was low to moderate and is an indication of the low inherent fertility status of the soil. The low status of the CEC in the soils of Abuja implies a low potential to hold nutrients. The low CEC in the pedons also suggests that the soil is dominated by low activity clay and this can be associated with low weathering activity of the soils, high leaching of basic actions and acidity (Mohammed *et al*., 2024). This conforms to the findings of Hassan *et al* (2011) when they reported that low CEC is attributed to clay type. This is because soils with large amount of clay and organic matter have higher CEC than sandy soils. Idoga and Azagaku (2005) observed that he relationship between clay content and CEC can be highly variable because different clay minerals have different cation exchange capacity.

**Base saturation**

The result of base saturation at the surface horizon of Agena soils in Abaji area council of the FCT was 880 g $kg^{-1}$ while within the profile depth, base saturation ranged from 783 – 867 g $kg^{-1}$. At the surface horizon of Nuku soils profile base saturation of the soil was 837 g $kg^{-1}$ while within the profile depth, base saturation ranged from 850 - 888 g $kg^{-1}$. Base saturation of the soils was moderate to high according to the ratings of Landon (1991) and Chude *et al* (2011). The distribution pattern showed an irregular increase with profile depth. The soils can be regarded as eutric since all the profiles have base saturation values above 500 g $kg^{-1}$ as provided by Soil Survey Staff (2022). This means that the soils are relatively fertile.

**Soil Taxonomic Classification**

The soil classification is shown in Table The soils of Agena and Nuku areas all in Abaji Area Council of the FCT possessed argillic horizons and base saturation up to 50 % and have been placed in the USDA order of Alfisols. Due to their ustic moisture regime, the were placed in the sub-order Ustalf and great group Haplustalf. The soils possess Kandic horizons due to high clay content in the sub surface horizons with low CEC. The soils also have red colour with hues of between 2.5 YR – 5YR and so have been placed in the subgroup kandic Rhodustalf which correlated with Rhodic Lixisol (Dystric) in the World Reference Base classification.

Table 5: Soil Classification

| Area Council | Location | USDA Soil Taxonomy | World Reference Base |
|---|---|---|---|
| Abaji | Agena | Kandic Rhodustalf | Rhodic Lixisol Dystric |
| | Nuku | Kandic Rhodustalf | Rhodic Lixisol Dystric |

**Sustainability Status of Soils of the Federal Capital Territory, Abuja**

Results of the sustainability status of agricultural soils of the FCT are presented in Table 6.

The analysis of the sustainability status of the soils of Agena in Abaji the FCT shows that Ksat, EC, $Al^{3+}$ and pH do not impose any constraint or limitation in the soils, and the level of coarse sand and bulk density posed only a slight limitation. However, WSA and soil texture posed a moderate level of limitation. The constraint imposed by MWD and SOC were severe. This placed the soil as being sustainable in status.

In the soils of Nuku, Ksat, EC, $Al^{3+}$, and pH posed no constraints or limitation to the soil. While coarse sand had a slight limitation. Other factors such as WSA, bulk density and soil texture had moderate limitations. Only MWD and SOC posed severe limitations. The cumulative weighing index placed the soils of Nuku as being sustainable.

The soil units at Agena and Nuku in Abaji Area council of the FCT are rated as "sustainable" has a soil sustainability rating of $> 20 \leq 25$. Being just sustainable implies that some properties still constitute limitations to the productivity of the soil.

Bulk density is one property that adds up to reduce the sustainability of the soil. This implies restriction to root growth, restriction to the transmission of water within the soil (Larson and Pierce, 1994; Oku *et al*., 2020). Water stable aggregate (WSA) and the size distribution of aggregates responsible for aggregation constituted limitations that ranged from severe to extreme. The limitations in WSA and MWD combines with unfavourable bulk density will render the soil prone to degradation and reduction in the sustainability of the soil. The soil organic carbon (SOC) levels in all the fields is a major concern and one major factor combining with other soil properties to imposed severe limitation and reduced the ability of the soil to continue to support crop production and other agronomic activities. Soil organic carbon is a property that serves as the "blood" of productive soil (Oku, *et al*., 2020). The availability of nutrients in the soil to enhance crop productivity and enhance the environmental quality of the soil is linked to the level of SOC (Harris *et al*., 1996). The levels of SOC in the fields are low from the study of the fertility of the fields. Hence crop productivity in the field is also expected to below.

Sustainability of soil with the prediction "with high input" needs specialized expert-recommended soil management practices and inputs for the fields. The inputs must be incorporated with high-quality green materials and inorganic materials. The high bulk density needs to be improved upon by introducing tillage. The SOC must be improved with organic amendments. With the improvement in SOC, the water-stable aggregate will increase and reduce or eliminate the limitations imposed by MWD on the soil. From this study and some previous studies, there is a direct relationship between soil health and sustainable land management (Gregorich *et al*., 1995). This supports the submission of Karlen *et al*., (1997) and Doran and Zeiss (2000). The critical component of sustainable agriculture and a farming system can only be sustainable when soil quality is maintained or improved (Larson and Pierce 1994). When soils become degraded, more resources in terms of time, money, energy, and chemicals will be needed to produce less-abundant crops of lower quality.

Table 6: Sustainability status of soils of Abaji

| Location | Soil indicators (0 – 30 cm) | Soil indicator values | Weighing factor | Limitation |
|---|---|---|---|---|
| | Coarse sand % | 12.04 | 2 | Slight |
| Agena | MWD (mm) | 1.00 | 4 | Severe |
| N=8.474786 | WSA (%) | 32 | 3 | Moderate |
| E=6.911066 | Ksat (cm $hr^{-1}$) | 5.00 | 1 | None |
| Alt. 172m | Bulk density (g $cm^{-3}$) | 1.34 | 2 | Slight |
| | Texture | Sandy loam | 3 | Moderate |
| | EC (dS $m^{-1}$) | 1.3 | 1 | None |
| | $Al^{+3}$ (cmol $kg^{-1}$) | 0.29 | 1 | None |
| | pH ($H_2O$) | 6.2 | 1 | None |
| | Soil organic carbon g $kg^{-1}$ | 2.04 | 4 | Severe |
| | *Cumulative index rating* | | *22* | *Sustainable* |
| | Coarse sand % | 10.00 | 2 | Slight |
| Nuku | MWD (mm) | 0.97 | 4 | Severe |
| N=8.516282 | WSA (%) | 30 | 3 | Moderate |
| E=7.036950 | Ksat (cm $hr^{-1}$) | 5.13 | 1 | None |
| Alt. 296m | Bulk density (g $cm^{-3}$) | 1.41 | 3 | Moderate |
| | Texture | Sandy loam | 3 | Moderate |
| | EC (dS $m^{-1}$) | 1.2 | 1 | None |
| | $Al^{+3}$ (cmol $kg^{-1}$) | 0.31 | 1 | None |
| | pH ($H_2O$) | 6.2 | 1 | None |
| | Soil organic carbon g $kg^{-1}$ | 1.96 | 4 | Severe |
| | *Cumulative index rating* | | *23* | *Sustainable* |

NB: MWD = mean weight diameter, WSA = water stable aggregate, Ksat = saturate hydraulic conductivity, EC = electrical conductivity, $Al^{3+}$ = aluminium, pH = soil reaction

**Conclusion and Recommendation**

The soils are of low fertility status and would therefore require significantly input of nutrients to maintain its productive capacity for a long time. Integrated nutrient management that requires incorporation of good inorganic fertilizers and organic manures is highly recommended. This will enhance the nutrient supply to plants and also improve the physical quality of the soils.

Mixed cropping with varying root depths holding the soil intact and absorbing nutrients from various levels of soil to enrich the top soil. In-situ manuring is recommended before the sowing and practicing of integrated soil fertility management (ISFM) which is knowledge-intensive rather than input-intensive approach that aims at raising productivity levels while maintaining the natural resource base, replenish soil nutrient pools, maximize on-farm recycling of nutrients, reduce nutrient losses to the environment and improve the efficiency of external inputs. The manure which is incorporated into the soil by basal application can be follow by the amendment of vermicompost as basal dressing at the root zone of each individual plant with drip irrigation system will help a lot in replenishing the soil.

Table 3: Morpho-physical properties of Soils of Abaji in the Federal Capital Territory

| Location | Horizon | Depth (cm) | Colour | Structure | Consistence | Inclusions | Boundary | Remarks | Sand g/kg | Silt g/kg | Clay g/kg | TC | S:C | Bd g/cm$^3$ | TP % | Ksat cm/hr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agena N=8.474786 E=6.911066 Alt. 172m | Ap | 0 - 23 | 7.5YR 4/4 Dark brown | 1fcr | nst.npl, fr,sft | 1-cm | CW | Affected by ploughing | 750 | 118 | 132 | LS | 0.89 | 1.33 | 49.81 | 5.05 |
| | Bt1 | 23 - 45 | 5YR 4/6 Yellowish red | 2fsbk | nst.npl, fr,sft | 1-cm | CW | | 674 | 146 | 186 | SL | 0.78 | 1.35 | 49.06 | 4.87 |
| | Bt2 | 45 - 70 | 5YR 6/6 Reddish yellow | 2msbk | Slst.slpl, fm,hd. | 1-fm | GI | Soils are rhodic, pockets of decayed roots from previous land clearing | 674 | 120 | 206 | SCL | 0.58 | 1.41 | 46.79 | 4.30 |
| | Bt3 | 70 - 103 | 2.5YR 4/6 Red | 3msbk | St.pl, vfm, hd. | 1 –ff | GI | Cutans visible | 660 | 135 | 265 | SCL | 0.51 | 1.52 | 42.64 | 3.45 |
| | BC | 103 - 145 | 10R 4/6 Red | 3mabk | St.pl, vfm, vhd | 1 –ff | DB | Fe and Mn patches, Ustic MR, rhodic red horizon, kandic horizon and cutans visible | 430 | 233 | 337 | CL | 0.69 | 1.60 | 39.62 | 2.86 |
| | C | 145 - 205 | 10R 4/6 Red | 3mabk | St.pl, vfm, vhd | | | Horizon very dense, cutans visible, kandic horizon, Fe and Mn patches common | 433 | 240 | 327 | CL | 0.73 | 1.60 | 39.62 | 2.83 |
| Nuku N=8.516282 E=7.036950 Alt. 296m | Ap | 0 -17 | 5YR 3/4 Dark reddish brown | 1fcr | nst.npl, fr,sft | 1 –cm | DB | Influenced by tillage and land clearing, earthworm castes are common sights on the surface soil. | 754 | 130 | 116 | SL | 1.12 | 1.28 | 51.70 | 5.52 |
| | Bt1 | 17 – 32 | 5YR 3/4 Dark reddish brown | 2msbk | nst.npl, fr,sft | 1 –cm 2 – fm | CW | Plinthic horizon. | 676 | 142 | 182 | SL | 0.78 | 1.35 | 49.06 | 4.74 |
| | Bt2 | 32 – 79 | 5YR 5/4 Reddish brown | 2msbk | Slst.slpl, fr, hd | 1 –cm | GI | Elluviation observed common | 654 | 131 | 205 | SCL | 0.64 | 1.46 | 44.91 | 3.66 |
| | Bt3 | 79 - 126 | 5YR 5/6 Yellowish red | 2msbk | St.pl, fm, hd | 1 –cm | DB | Cutans are visible, Argilic horizon with clay films on peds. | 618 | 131 | 251 | SCL | 0.52 | 1.55 | 41.51 | 2.98 |
| | BC | 126 - 188 | 5YR 5/6 Yellowish red | 3mabk | vst.vpl, vfm, vhd | 6 –cm | AS | Partial weathering observed | 447 | 250 | 303 | CL | 0.83 | 1.58 | 40.38 | 2.63 |
| | C | 188 - 200 | 5YR 5/6 Yelowish red | 3msbk | St.pl, fm, hd | 1 –cm | | Horizon is partially weathered with massive parent materials undergoing weathering | 604 | 122 | 274 | SCL | 0.45 | 1.60 | 39.62 | 2.05 |

Texture : SL sandy loam, LS = loamy sand, SCL = sandy clay loam, CL = clay loam, C = clay; TC = textural class, S:C = silt to clay ratio, Bd = bulk density, TP = total porosity, Ksat = satuyrated hydraulic conductivity.
Structure : 0 = structureless, 1 = weak, 2 = moderate, 3 = strong, f = fine, m = medium, c= coarse, cr = crumb, gr = granular, pl = platy, bk = blocky, abk = angular blocky, sbk = sub-angular blocky, pr = prismatic, cpr = columnar.
Consistence : sst = non sticky, npl = non plastic, st = sticky, p,l = plastic, fr = friable, vfr very friable, ls = loose, sf = soft, hd = hard, vst = very sticky, vpl = plastic, vhd = very hard, fm = firm, vfm = very firm, sst = slightly sticky, spl = slightly plastic
Inclusion : 1 = roots, 2 = gravels, 3 = stones, 4 = artefacts, 5 = concretions, 6 = parent materials, 7 = bed rocks, ff = few and fine, fm = few and medium, fc = few and coarse, cf = common and fine, cm = common and medium, cc = common and coarse, mf = many and fine, mm = many and medium, mc = many and coarse
Boundary : AS = abrupt & smooth, CW = clear & wavy, GI = gradual & irregular, DB = diffused & broken

Table 4: Some Chemical properties of Soils of Abaji in the FCT Abuja

| Location | Horizon | Depth (cm) | pH 1:1 H$_2$O | pH 1:1 KCl | EC dS cm$^{-1}$ | OC g kg$^{-1}$ | TN g kg$^{-1}$ | S mg kg$^{-1}$ | AP mg kg$^{-1}$ | Ca | Mg | K | Na | Ex.H | Ex.Al | EA | TEB | CEC | B.sat g kg$^{-1}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | cmol kg$^{-1}$ | | | | | | | | | |
| Agena N=8.474786 E=6.911066 Alt. 172m | Ap | 0 - 23 | 6.2 | 5.6 | 0.13 | 1.11 | 0.10 | 0.45 | 10 | 6.70 | 4.33 | 0.18 | 0.03 | 0.80 | 0.28 | 1.08 | 11.24 | 12.77 | 880 |
| | Bt1 | 23 - 45 | 6.3 | 5.5 | 0.12 | 2.98 | 0.09 | 1.20 | 7 | 5.46 | 3.72 | 0.18 | 0.05 | 0.54 | 0.30 | 0.84 | 9.41 | 10.86 | 867 |
| | Bt2 | 45 - 70 | 6.2 | 5.5 | 0.14 | 1.90 | 0.08 | 0.92 | 6 | 5.33 | 3.96 | 0.17 | 0.03 | 0.66 | 0.30 | 0.96 | 9.49 | 10.98 | 864 |
| | Bt3 | 70 - 103 | 6.2 | 5.6 | 0.12 | 1.10 | 0.10 | 0.33 | 9 | 4.69 | 2.99 | 0.27 | 0.03 | 0.84 | 0.24 | 1.08 | 7.98 | 9.76 | 818 |
| | BC | 103 - 145 | 6.3 | 5.6 | 0.13 | 1.00 | 0.09 | 0.30 | 8 | 7.41 | 2.86 | 0.13 | 0.04 | 1.02 | 0.18 | 1.20 | 10.44 | 12.29 | 850 |
| | C | 145 - 205 | 6.3 | 5.4 | 0.11 | 1.00 | 0.09 | 0.10 | 11 | 3.91 | 2.11 | 0.10 | 0.06 | 0.80 | 0.28 | 1.08 | 6.18 | 7.89 | 783 |
| Nuku N=8.516282 E=7.036950 Alt. 296m | Ap | 0 -17 | 6.3 | 5.4 | 0.13 | 2.97 | 0.09 | 1.30 | 17 | 4.33 | 2.91 | 0.13 | 0.06 | 0.50 | 0.34 | 0.84 | 7.43 | 8.88 | 837 |
| | Bt1 | 17 – 32 | 6.2 | 5.5 | 0.10 | 0.95 | 0.09 | 0.62 | 15 | 5.36 | 4.21 | 0.17 | 0.09 | 0.80 | 0.28 | 1.08 | 9.83 | 11.07 | 888 |
| | Bt2 | 32 – 79 | 6.4 | 5.6 | 0.11 | 2.96 | 0.05 | 1.20 | 20 | 5.74 | 3.46 | 0.08 | 0.06 | 0.98 | 0.22 | 1.20 | 9.34 | 10.95 | 853 |
| | Bt3 | 79 - 126 | 6.4 | 5.5 | 0.12 | 0.96 | 0.09 | 1.02 | 20 | 6.22 | 4.11 | 0.09 | 0.03 | 0.80 | 0.26 | 1.06 | 10.45 | 12.29 | 850 |
| | BC | 126 - 188 | 6.5 | 5.5 | 0.13 | 0.93 | 0.08 | 0.55 | 18 | 5.41 | 3.91 | 0.10 | 0.07 | 0.76 | 0.20 | 0.96 | 9.49 | 11.09 | 856 |
| | C | 188 - 200 | 6.5 | 5.5 | 0.11 | 1.13 | 0.10 | 0.49 | 18 | 5.61 | 1.36 | 0.16 | 0.02 | 0.88 | 0.20 | 1.08 | 10.15 | 11.88 | 854 |

NB: EC = electrical conductivity, OC = organic carbon, TN = total Nitrogen, S =available sulphur, Ca = calcium, Mg = magnesium, Ex.H = exchangeable hydrogen, Ex.Al = exchangeable aluminium, EA = exchangeable acidity, CEC = cation exchange capacity, B.sat = base saturation, TEB = total exchangeable bases.

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