Soil Quality Assessment of Different Land Use in Kabba Southern Guinea
Savannah of Nigeria

Abstract
The study assessed the soil qualities of five land use types; Oil palm plantation, Nursery site, Forest (Teak), Citrus orchard and Arable Crop land in Kabba College of Agriculture using selected biological indicators which include Organic Carbon (OC), Total Nitrogen (TN), Microbial Biomass Carbon (MBC) and Microbial Biomass Nitrogen (MBN). An area of 40 m x 30 m that is representative of each land use was selected, sampled and analyzed following standard procedures for laboratory analysis. The highest values of OC (18.41 g/kg) and TN (7.95 g/kg) was obtained at the nursery site followed by Oil Palm (OC: 14.12 g/kg and TN: 6.56 g/kg), the lowest values was obtained at the Arable Crops site (OC: 10.53 g/kg and TN: 5.20 g/kg). The MBC values ranged from 307 – 498 mg/kg across the land use studied. The MBN values obtained in this study ranged between 16.93 - 34.41 mg/kg. The SMBC/SMBN ratios obtained in this study were relatively high and in the following order Forest land (26.5 mg/kg) > Oil Palm Plantation (21.3 mg/kg) > Citrus orchard (19.5 mg/kg) > Nursery site (15.9 mg/kg) > Arable Crops land (12.2 mg/kg) respectively indicating the predominance of fungi in these soils. It is recommended that sustainable practices that will encourage replenishment of C and N into the soil should be adopted in the study area.

Keywords: Soil Quality, Land use, Organic Carbon, Total Nitrogen, Microbial Biomass

Introduction
Soils cover most lands of the earth, but regarding their service for humans they are a limited and largely non-renewable resource (Blum, 2006). On the globe about 3.2 billion hectares are used as arable land, which is about a quarter of the total land area (Davis and Masten, 2003). The development and survival of civilizations has been based on the performance of soils on land to provide food and further essential goods for humans (Hillel, 2009). Global issues of the 21st century like food security, demands of energy and water, climate change and biodiversity are associated with the sustainable use of soils (Lal, 2009) and feeding about 10 billion people is one of the greatest challenges of our century. Borlaug (2007) stated: “The battle to alleviate poverty and improve human health and productivity will require dynamic agricultural development”. There are serious concerns that increase of global cereal yield trends are not fast enough to meet expected demands (Cassmann et al., 2003). However, agricultural development cannot be intensified regardless of the bearing capacity of soils, ecosystems and socio-economical environment. It has to be imbedded within balanced strategies to develop multifunctional landscapes on our planet (Helming et al., 2008). Handling of soils by societies must be in a sustainable way in order to maintain the function of all global ecosystems (Hillel, 2009).
The soil protection strategy of the European Commission (EC, 2006) addresses “biomass production” as a main soil function which must be maintained sustainably and this is referred to as the “productivity function”. The productivity function is related to the most common definition of soil quality as “the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation” (Karlen et al., 1997). Based on this definition, the objective comes close to the assessment of “agricultural soil quality”.

Scientific assessment of soil quality is essential to monitor sustainability of agricultural systems. This is usually assessed in the context of the soil’s inherent capabilities, the desired uses of the soil, and the scale of assessment. The goal of soil quality research is to learn to manage soil for long-term productivity and environmental integrity. Soil scientists have extensively examined characteristics such as organic matter, erosion rates, and nutrient availability. Studying soil quality is about site-specific land management decision making, rather than general land use assessment. The result of soil quality research is not a map of optimal land uses and a prescription for optimal land management but rather involved many maps of soil conditions over time, an understanding of the processes that tie management to soil performance so that managers can make better site-specific decisions, and more direct linkages between the work of farmers and researchers.

Soil quality is inextricably linked to sustainability (Doran and Parkin, 1994); and understanding soil quality means ability to manage the soil, so that it functions optimally for the present while not degraded for future use. The sustainability of agricultural land-use can only be guaranteed if the processes of material and energy flow associated with crop production were controlled and influenced especially through its management and maintenance. However, to assess the capacity of soil to perform its functions, a number of soil parameters need to be considered in an integrated manner. Only a full assessment of soil functional capacities can comprehensively indicate the status and trends in soil quality. Policy planning and decision making can also be based only on clear information on the status of soil quality and on the possible effect of policies on soil quality. The Objectives of the study are:

1. To determine the soil quality of the study area.

2. To compare the soil quality of the different land use in the area.
Materials and Methods

Description of the Study Area: The study area is located in Kabba, Southern Guinea Savanna Ecological Zone of Nigeria (latitude 07°53′N and 07°5′N and Longitude 6°8′E and 6°3′E). The rainfall spans from April to November with the peak in June to September while the dry season extends from December to March. The mean annual rainfall is 1,570 mm per annum with an annual temperature range of 18°C - 32°C and the Mean Relative Humidity is 59% (Meteorological Data, 2014).

The main vegetation of the area is; tall grasses, shrubs, some trees, plantains, oil palm, etc. Some parts of the area however, had been put to cultivation of arable crops like maize and tubers such as yam and cassava while a part of the site is used for field experiments with experimental crops such as cowpea, cassava, maize tomato being planted. On the whole, human activities (cultivation) influenced the vegetation. The major soil orders within the experimental sites are Gleysol and Alfisol (Babalola, 2011). The land uses under consideration include: Oil Palm Plantation, Nursery Site, Arable Crops Land, Citrus Orchard and Forest Land.

Soil Sampling and Laboratory Analysis: An area of 40 m x 30 m, that is representative of each of the land use was selected for soil sampling. The area selected was demarcated to four and composite soil samples were collected at each of the demarcated area at soil depth 30 cm. Part of the sample was stored in plastic bags at 4°C for soil microbial biomass (SMB) determinations i.e. Microbial Biomass Carbon (MBC) and Microbial Biomass Nitrogen (MBN). The remaining soil was air-dried, sieved to 2 mm and stored at ambient temperature for analysis of other soil properties.

Total Nitrogen (TN) was determined by the Kjeldahl digestion procedure (Bremner and Mulvaney, 1982). Organic Carbon (OC) was determined by digesting the soil at 130°C for 30 min with concentrated H₂SO₄ and K₂Cr₂O₇, after which OC was, determined calorimetrically (Anderson and Ingram, 1993). Soil Microbial Biomass Carbon (MBC) and Soil Microbial Biomass Nitrogen (MBN) were determined by the chloroform fumigation–extraction method (Anderson and Ingram, 1993) in closed desiccators for 24 hrs at 25°C. MBC/MBN ratio, MBC/OC ratio and MBN/TN ratio (%) were calculated from the results of the analysis. Data collected were presented as shown in Figures 1, 2 and 3 below.

Results and Discussion

Organic Carbon and Total Nitrogen: Results on Organic Carbon (OC) and Total Nitrogen (TN) are presented in Fig. 1. The highest values of OC (18.41 g/kg) and TN (7.95 g/kg) was obtained at the Nursery site followed by Oil Palm OC (14.12 g/kg) and TN (6.56 g/kg), the
lowest values was obtained at the Arable Crops site OC (10.53 g/kg) and TN (5.20 g/kg). This result is in agreement with the findings of Adeboye et al., (2011) and generally the values were low but in agreement with reports for Nigerian soils (Fasina, 2004; Babalola et al., 2011).

The high results obtained at the nursery and Oil palm site could be attributed to all year round cultivation, adequate nutrient input from fertilizer and manure, returns of decay organic materials to the soil in the form of decaying roots, litter and crop residues (Adeboye et al., 2011). Although higher OC have been obtained with fertilizer application in a savanna Alfisol in Nigeria (Ogunwole, 2005), annual cropping reduces C loss from soils (Collins et al., 1992).

Organic C has been identified as the most sensitive soil quality indicator suggesting that within a narrow range of soil, Organic C may serve as a suitable indicator of soil quality. Several studies reported that soil organic matter fractionation may offer further insight into soil fertility changes and the sustainability of past management history (Barrios et al., 1996; Kapkiyai et al., 1999). In this study, soils from land use studied contained different Organic Carbon levels that reflect the management practices on them. This observation agrees with Kapkiyai et al. (1999) who compared C fraction changes in different soil management strategies after 18 years of continuous cultivation in a long-term, on-station experiment located on the Kikuyu Red Clay.

Microbial Properties: Results on microbial properties were presented in Figure 1, 2 and 3. The MBC values ranged from 307 – 498 mg/kg across the land use studied. These values are in agreement with of values of 115 – 1231 mg/kg reported by (Anderson and Domsch 1989) and (Insam et al., 1989) and 61 – 1620 mg/kg by (Srivastava and Singh, 1988) in other land use types and terrestrial ecosystems. Also the values are in agreement with the findings of Adeoye (2011); 182 – 766 mg/kg and Onweremadu et al., (2011); 131 – 270 mg/kg for Nigerian Soils in other land use types and terrestrial ecosystems. However, it is lower than the values of 1000 – 2000 mg/kg recorded in humid tropical forest in Amazonia (Henrot and Robertson, 1994).

The lowest value of MBC 307 mg/kg was recorded at the arable crops site. This is responsible for the lowest OC value (5.2 mg/kg) recorded at the site and can be attributed to tillage, poor return of plant residue as a result of harvesting (Babalola et al., 2012). Relationship between Microbial Biomass and OC has been established (Adeoye, 2011; Doran and Parkin, 1994). The MBN values obtained in this study ranged between 16.93 - 34.41
mg/kg, they are in agreement with reported values of 18.59 - 44.78 mg/kg by Adeboye (2011) and 25.6 - 42.2 mg/kg by Singh and Singh (1992). The Nursery site has the highest OC, TN, MBC and MBN value and this has been attributed to round the year cultivation with application of inorganic and organic fertilization (Adeboye, 2011; Singh and Singh, 1992).

The MBC/MBN ratio has been reported to be a function the structure of the microbial community (Adeboye, 2011). A low MBC/MBN ratio indicates that the microbial biomass contains a higher proportion of bacteria whereas a high value suggests that fungi predominate in the microbial population. The SMBC/SMBN ratios obtained in this study were relatively high, ranging from 15.9 – 26.5 mg/kg indicating the predominance of fungi in these soils. The SMBC and SMBN when expressed as percentages of SOC and STN respectively give an estimation of the quantities of nutrients in the microbial biomass, organic matter dynamics and substrate availability in soils (Sparling, 1992). Reports in this study revealed that MBC accounted for between 2.7 - 4.1 % of OC while MBN was 0.3 - 0.4% of STN. This result also agrees with the findings of Adeboye (2011). However, the MBN as a percentage of TN obtained are lower than the ranges reported in literature by other workers for arable, pasture and forest; and the low values indicate that the microbial biomass is not important as a sink for N in these areas (Singh and Singh, 1992).

Conclusion

Indicators studied in this research OC, TN, biomass C and N proved to be suitable biological indicators of soil quality in the study area and they all agree with findings of past research on the subject matter. Round the year cultivation practice in the Nursery site improves the quality of soil in the study area. Microbial activities are more active in the Nursery and Plantation areas than the Arable land due to having more C and N. It is therefore recommended that sustainable practices such as use of organic manure, green manure, planting of legumes as sole crop and intercrop that will encourage replenishment of C and N into the soil should be adopted in the study area.

References


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Figure 1: Effect of Land Use on Organic Carbon and Total Nitrogen

Figure 2: Effect of Land Use on Microbial Biomass Carbon (MBC) and Microbial Biomass Nitrogen
Figure 3: Effect of Land Use on Soil Microbial Biomass Ratio