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# Assessment of soil health indices under three land use types

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**Abstract**

Soil responses to human activities are usually evident in alterations in soil properties under different land-use types . A field study was conducted to quantify the effect of three land-use types on soil properties in a tropical rainforest ecosystem in Edo State, Nigeria. Soil samples collected from a citrus orchard, riverside, and residential area at 0 – 45 cm depth were assessed for soil fertility indices and microbial population. Three soil physical health indicators (organic matter, silt and clay) were integrated to estimate soil structural stability (S ) using the soil structural stability index. Soil organic matter varied significantly ($p < 0.05$) among LUTs, and was lower in the citrus orchard and residential area compared with riverside by 50.0 % and 66.5 %, respectively. There was no substantial difference in the bacterial count which was lower in the citrus orchard and residential area than riverside by 29.5 % and 49.4 %, respectively. Corresponding values for fungal count were also lower in the citrus orchard and residential areas relative to the riverside by 20.4 % and 10.8 %. Soil structural stability differed significantly ($p < 0.05$) among land-use types, and was higher by 108.9 % and 66.3 % in riverside compared with the residential area and citrus orchard, respectively. Furthermore, 25.4 % and 1.2 % of soil structural stability were credited to changes in soil bacterial and fungal counts. Hence, improved management of organic matter, especially in the citrus orchard and residential area, could enhance microbial growth and increase soil structural stability.

Keywords: Land use types, Soil organic matter, Soil bacteria, Soil fungi, Soil structural stability
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## 1.0 Introduction

Human activities in the form of land use are one of the major causes of changes in soil health. Among them, land cultivation and other agricultural practices have been reported to either improve or degrade soil health. For example, changes in land use types (LUTs) and management practices such as the cultivation of deforested land may rapidly diminish soil health (Kang and Okoro, 1970), while Gochin and Asgam (2008) reported a 41-89 % less dispersible clay in the forest than in cultivated areas, averring that frequent cultivation leads to deterioration of soil health. Soil health is the capacity of soil to function as a vital living system, within the ecosystem and land-use boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and promote plant and animal health (Doran and Zeiss, 2000). Alike soil quality assessment, soil health assessment could be expensive to conduct. Hence, soil properties, often referred to as soil health indices, that are sensitive to changes and provide information of the ability of soils to function as a basic component of the ecosystem is often used by experts to access information about soil health. These properties have been reported to positively correlate with land-use changes, and have been affirmed to reflect soil health status (Oguike and Mbagwu, 2009; Martinez *et al.*, 2012; Igwe and Obalum, 2013). For instance, changes in soil organic matter, porosity and bulk density due to changes in land-use practices have been reported in several studies (Borman and Klassen, 2008; Haghighi *et al.*, 2010). Aliku and Oshunsanya (2018) also reported variations in soil hydrophysical properties under different -LUTs in three agro-ecological zones in Nigeria, while Doran and Zeiss (2000) noted an increase in awareness of the importance and utility of soil organisms as indicators of soil quality and determinants of soil health.

Regarding agroecology, Kang and Okoro (1970) reported that ecologically sensitive components of the tropical rainforest ecosystem are not able to buffer the effects of agricultural practices and other land-use changes. Furthermore, anthropogenic reductions in soil health, and its components, are a pressing ecological concern (Doran and Zeiss, 2000). However, only few studies have examined the impacts of land use on soil health indices in the rainforest agroecology in Nigeria (Ogboghodo and Aliku, 2015; Uquetan *et al.*, 2017). Detection of changes in these components could provide information on soil health and could assist in proffering management practices for its improvement. Also, knowledge of soil properties and processes could guide remediation or reclamation of disturbed or damaged soil (Gonzalez *et al.*, 2014). This study examines the response of some selected soil health indices to three land-use types in rainforest agroecology in Nigeria.

## 2.0 Materials and methods

*2.1 Site area*

The study was conducted in the University of Benin, Benin City (latitude 06° 41′ N and longitude 06° 36′ E), Edo State. It is located in the rainforest agro-ecological zone of Nigeria. It has a tropical climate pattern with distinct rainy and dry seasons. Its mean annual rainfall amount ranges from 1200 mm to 1825 mm, while its temperature ranges from 15 □ to 34 □ (Ogboghodo and Aliku, 2015; Aliku and Oshunsanya, 2018). The soils are poorly drained alluvial kandiudult deposits of the River Niger developed from underlying Basement Complex Rocks (FAO-UNESCO-ISRIC, 1990).

*Selection of land use types, soil sampling and analysis*

Three LUTs (Citrus, Residential area and Riverside) were identified and selected to examine their effects on soil health indices. Soil samples were collected from each LUT at 0-45 cm depth with an auger. The samples were composited and homogenised before extracting triplicate sub-samples per LUT for analysis of soil health indices. The soil samples were analysed using standard procedures described in Ogboghodo and Aliku (2015) and Aliku and Oshunsanya (2018), while soil structural stability (S) was estimated using the structural stability index described by Pieri (1989):

$$S = \frac{\text{Organic matter content (\%)} \times 100}{\text{Clay (\%)} + \text{Silt (\%)}} \quad (1)$$

*Statistical analysis*

Data were analysed using the completely randomised design procedure of Analysis of Variance (ANOVA) to determine the effects of LUTs on soil health indices. Significant difference means were grouped using Duncan Multiple Range Test (DMRT), and the probability level was set at 5%. The relationships among the soil health indices was assessed by subjecting them to 2-tailed Pearson Moment Correlation Analysis (PMCA). Simple linear regression analysis was used to assess the association between soil microbes and soil structural stability. All analyses were performed using GenStat Discovery Statistical Package (16$^{th}$ Edition).

## 3.0 Results and Discussion

*3.1 Soil chemical indices*

Table 1 presents the chemical health indices of soils under three LUTs. Soil pH differed significantly ($p < 0.5$) among the LUTs and was higher in riverside by 3.7 % and 33.3 % compared with residential area and citrus orchard, respectively. There was also significant ($p < 0.05$) difference in soil organic carbon among the LUTs. Comparatively, residential area and citrus orchard had 66.5 % and 50.0 % lower organic carbon than riverside. There was also 57.1 % and 35.7 % lower total nitrogen in soils in the residential area and citrus orchard compared with riverside. Available phosphorus did not vary significantly ($p < 0.05$) among the LUTs. However, the soil in riverside was higher by 28.6 % and 80.0 % than those in a residential area and citrus orchard, respectively. The dominant soil chemical indices characterised by superior organic carbon, total nitrogen and available phosphorus in riverside could be ascribed to higher amount of deposited and accumulated organic materials with little or no reduction relative to residential area and citrus orchard. This result supports the findings of Gochin and Asgam (2008) who noted that frequent cultivation and other human activities lead to deterioration of soil health.

*3.2 Soil biological indices*

The effect of LUTs on soil biological health indices are shown in Table 2. There was a significant ($p < 0.05$) variation in the organic matter among the LUTs. Citrus orchard and residential areas were lower in organic matter by 50.2 % and 66.5 % relative to the riverside. There was no substantial difference in the bacterial count which was lower in citrus orchard and residential areas than riverside by 29.5 % and 49.4 %, respectively. Corresponding values for fungal count were also lower in the citrus orchard and residential area relative to the riverside by 20.4 % and 10.8 %. The superior microbial population in the riverside could be attributed to its higher organic matter content relative to the citrus orchard and residential area. This corroborates the results of other authors who reported a higher number of heterotrophic fungi and bacteria due to an increase in organic carbon, and averred that as mineralization of organic materials in soil continues, multiplication of organisms also increases (Ogboghodo and Aliku, 2015; Velmourougane, 2016).

*3.3 Soil physical indices*

The physical health indices of soil as influenced by LUTs are presented in Table 3. There was a significant ($p < 0.05$) difference in a sand fraction which was higher in a residential area by 1.4 % and 3.4 % relative to citrus orchard and riverside. Conversely, silt was significantly ($p < 0.05$) higher in the riverside by 71.4 % and 63.6 % compared with the residential area and citrus orchard, respectively. There was no significant ($p < 0.05$) difference in clay content among the LUTs. However, the riverside was higher in clay than residential area and citrus orchard by 32.6 % and 7.0 %, respectively. The  among the LUTs differed significantly ($p < 0.05$), and was higher in riverside by 66.3 % and 108.9 % compared with citrus orchard and residential area, respectively. The superior physical attributes and structural stability in riverside could be attributed to its high clay and organic matter content which are responsible for the aggregation and stability of soil structure . This result is corroborated by the findings of Papadopoulos *et al.* (2006) who reported that organic management significantly affects soil structure and enhances biological activities with positive effects on the environment.

*3.4 Relationships among soil health indices*

Table 4 presents the relationship among the soil health indices. Organic matter had significant and positive correlations with soil total nitrogen ($r = 0.989$, $p < 0.01$), soil bacteria ($r = 0.799$, $p < 0.01$) and soil structural stability ($r = 0.903$, $p < 0.01$), suggesting that higher amount of organic matter and its mineralization will enhance growth of bacteria population, culminating into improved soil structure. Our results also showed a positive correlation exists between soil fungi and soil structural stability ($r = 0.111$, $p = 0.05$). However, this was not significant, indicating that soil bacteria could be higher than soil fungi in their contributions to soil structural stability. This was strengthened by Figure 1 which shows that 25.4 % of soil S was credited to changes in soil bacteria, while and 1.2 % was due to the effects of soil fungi. These results corroborate the assertion of Aliku et al. (2019) who reported that the addition of organic matter alters soil physical properties, especially soil structural characteristics, which regulate soil functions and processes, and enhances biological activities.

*Table 1: Soil chemical health indices as influenced by land use types*

| **Land use types** | **pH** | **Organic carbon** | **Total nitrogen** | **Avail. phosphorus (mg□Kg$^{-1}$)** |
|---|---|---|---|---|
| | | g□Kg$^{-1}$ | | |
| Citrus orchard | 4.2b | 9.1b | 0.9b | 0.5 |
| Residential area | 5.4a | 6.1b | 0.6c | 0.7 |
| Riverside | 5.6a | 18.2a | 1.4a | 0.9 |
| $SED_{0.05}$ | 0.37 | 1.45 | 0.11 | ns |

SED: Standard error of differences of means

*Table 2: Effect of land use types on soil biological health indices*

| **Land use types** | **Organic matter (g□Kg$^{-1}$)** | **Bacteria** | **Fungi** |
|---|---|---|---|
| | | cfu/g soil | |
| Citrus orchard | 15.6b | 43.0 | 28.9 |
| Residential area | 10.5b | 28.2 | 25.8 |
| Riverside | 31.3a | 55.7 | 32.4 |
| $SED_{0.05}$ | 2.50 | ns | ns |

SED: Standard error of differences of means

*Table 3: Soil physical properties as influenced by land-use types*

| Land use types | Sand | Silt | Clay | Soil structural stability |
|---|---|---|---|---|
| | | g□Kg$^{-1}$ | | |
| Citrus orchard | 920.7ab | 22.3b | 57.3 | 19.6b |
| Residential area | 933.3a | 21.0b | 46.0 | 15.7b |
| Riverside | 903.0b | 35.7a | 61.3 | 32.8a |
| $SED_{0.05}$ | 1.09 | 0.36 | ns | 2.60 |

SED: Standard error of differences of means

*Table 4: Correlation coefficient among soil health indices*

| | **Org. matter** | **Total N** | **Avail. P** | **pH** | **Bacteria** | **Fungi** | **Sand** | **Silt** | **Clay** | **S** |
|---|---|---|---|---|---|---|---|---|---|---|
| Org. matter | 1 | 0.989** | 0.441 | 0.339 | 0.799** | 0.440 | -0.861** | 0.940** | 0.703* | 0.903** |
| Total N | | 1 | 0.489 | 0.246 | 0.789* | 0.392 | -0.835** | 0.894** | 0.693* | 0.917** |
| Avail. P | | | 1 | 0.154 | 0.336 | 0.063 | -0.289 | 0.397 | 0.261 | 0.404 |
| pH | | | | 1 | -0.029 | 0.247 | -0.172 | 0.424 | -0.116 | 0.347 |
| Bacteria | | | | | 1 | 0.560 | -0.954** | 0.870** | 0.955** | 0.504 |
| Fungi | | | | | | 1 | -0.731* | 0.590 | 0.726* | 0.111 |
| Sand | | | | | | | 1 | -0.933** | -0.941** | -0.572 |
| Silt | | | | | | | | 1 | 0.793* | 0.721* |
| Clay | | | | | | | | | 1 | 0.364 |
| S | | | | | | | | | | 1 |

** Correlation is significant at the 0.01 level (2-tailed), * Correlation is significant at the 0.05 level (2-tailed), S is soil structural stability.

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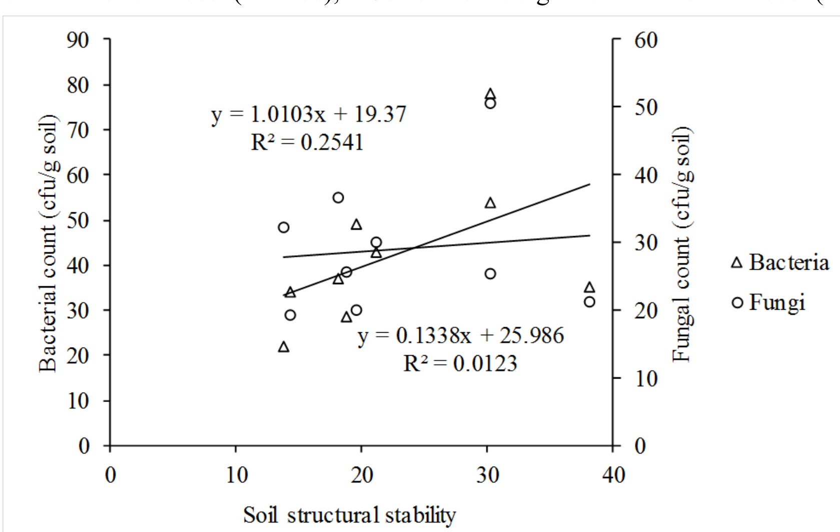


Figure 1: Relationship between soil structural stability, and soil bacteria and fungi

## 4.0 Conclusions

LUTs involving cultivation and other anthropogenic activities resulting in a reduction of organic matter than its addition, as in the case of citrus orchard and residential area, diminishes soil health. Riverside had better soil health than citrus orchard and residential area due to its high organic matter content, and consequent high microbial population and improved soil structural stability. Our results showed that organic matter is critical for enhancing microbial growth and improving soil structural stability. Bacteria appeared to be a higher contributor to soil structural stability and soil health than fungi.

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