Relationship between Aggregate Stability, Sand: Clay Ratio and Electrical Conductivity in Plantation Soils

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Abstract
A study was carried out at the Micheal Okpara University of Agriculture, Umudike, plantation farms to monitor changes in aggregate stability sand/clay ratio and organic matter content in these soils. Soil samples were collected from these plantations, (oil palm plantation and pineapple) with soil auger at two depths 0-15cm and 15-30cm and analyzed for selected properties. Results show that the soils under rubber plantation had the highest aggregate stability at both depths (70%-80%) compared to the other soils (26%-44%); soil under pineapple had the highest sand/clay ratio(1.94), while the soil under oil palm had the highest exchangeable sodium percentage(4.66%), compared to the other soils. There were direct relationship between soil aggregate stability and organic matter content and also between sand/clay ratio and organic matter in the soils, however an inverse relationship exist between Sand :Clay ratio and aggregate stability while the exchangeable sodium percentage(ESP) was inversely related to aggregate stability. Generally the results show that the soils from these plantation sites could be managed efficiently by specifically enhancing the ESP since all the properties considered was had significant level of correlation with ESP with a coefficient of determination (r²) of about 62% indicating that the ESP exerted well over 60% control on the selected soil properties.

Keywords: exchangeable sodium percentage, (ESP), sand:clay ratio, aggregate stability, plantation soils, coefficient of determination (r²)

Introduction
Aggregate stability of a soil defines the resistance of soil structure against mechanical or physico-chemical destructive forces (Duniway, et. al., 2009), and soil structure is one of the factors controlling plant growth by its influence on root penetration, soil temperature and gas diffusion, water transport and seedling emergence and therefore it is an important soil characteristic for farmers. Soil structure defines the combination or arrangement of primary soil particles into compound elements, which are separated from adjoining structural elements by surfaces of weakness. Thus soil texture, soil structure, and the type of clay mineral, organic matter content and type, cementing agents as well as cropping history of a particular land collectively influence the aggregate stability (Goldberg et. al., 1988). According to Gupta1 and Sharma (1990), the presence of excessive amounts of exchangeable sodium reverses the process of
aggregation and causes soil aggregates to disperse into their constituent individual soil particles. This is known as deflocculating and occurs in sodic soils which are reported to contain high level of sodium relative to the other exchangeable cations (i.e. calcium, magnesium and potassium). Soils around the Micheal Okpara University of Agriculture have been subjected to different plantation crops such as oil palm, pineapple, citrus, and rubber; these economic plants have suffered neglect both in management and in proliferation. The African oil palm *Elaeis guineensis* is native to West Africa, occurring between Angola and Gambia. They are used in commercial agriculture in the production of palm oil. They grow in a wide range of soil types, provided good drainage and pH between 4 and 7; tolerates periodic flooding or a high water table; many soils are alluvial in nature, (*Hartley*, 1988). Research reports of the Department of Botany and Plant Pathology (2009), Purdue University also indicates that plantation plants like pineapple cannot stand water logging, though the plant is surprisingly drought tolerant, adequate soil moisture is necessary for good fruit production. While natural rubber is an elastomer (an elastic hydrocarbon polymer) that was originally derived from a milky colloidal suspension, or latex, found in the sap of some plants. The purified form of natural rubber is the chemical polyisoprene, which can also be produced synthetically. Natural rubber is used extensively in many applications and products, as is synthetic rubber. The soil requirement of the plant is generally well-drained weathered soil consisting of laterite, lateritic types, and sedimentary types, nonlateritic red or alluvial soils. (Wikipedia, 2008)

It is obvious that these three high economic utility crops when effectively managed can help eradicate or reduce the global economic recess of many nations. Therefore the objective of this study was to determine the relationship between sand/clay ratio, aggregate stability and exchangeable sodium percentage of soils exposed to rubber, oil palm and pineapple plantations, to obtain repeatable soil quality information which if applied would enable sustainable productivity of these plantation crops.

**Materials and Methods**

**Study Site**

Soils were collected from the rubber plantation, oil palm plantation and pineapple orchard at Michael Okpara University of Agriculture, Umudike located on latitude 5° 28’ North and longitude 7° 32’ East with an elevation of 122m above sea level. The area is characterized by mean annual rainfall range of 1512 – 2731mm and relative humidity of 63-80% (N.R.C.R.I, Umudike, 2005).

**Sample Collection and Laboratory Analysis**

Soil samples were collected in triplicates from the plantation sites, with soil auger at two depths (0-15cm and 15-30cm) put into a paper bag labeled and taken into
the laboratory for analysis. The soil physical properties analyzed were; particle size
distribution determined by the hydrometer method of Bouyoucous, (1951) as modified
by Osodeke, (1997), exchangeable K, Ca, Mg and Na determined by extracting soil
samples in 1N NH₄OAC, and the filtrate collected for elemental determination (Jones,
2001).
The sand-clay ratio was calculated using the formula:
\[
\text{Sand/Clay Ratio} = \frac{\% \text{ Sand}}{\% \text{ Clay}}
\]
equation 1

Aggregate stability was determined by the mean weight diameter as described by
Kemper and Chepil, (1965), percent mean weight diameter (%MWD) was calculated
using the equation below;

\[
\% \text{MWD} = \frac{\sum X_i W_i \times 100}{1}
\]
equation 2

Where;
- \( X_i \) = Arithmetic mean diameter of \( i = 1 \) and sieve opening (mm)
- \( W_i \) = \( M_i / M_t \)
- \( M_i \) = soil sample in the respective sieve after drying (g)
- \( M_t \) = Total weight of initial materials.

The exchangeable sodium percentage (ESP) was calculated using the formula below:

\[
\text{ESP} = \frac{\text{Exchangeable } \{ (\text{Na} / (\text{Ca + Mg + K + Na}) \} \times 100}{1}
\]
equation 3

Data Analysis
Data collected was subjected to analysis of variance (ANOVA) using a 3X2 factorial in
Randomized complete block design (RCBD). Means were separated using Fisher’s least
significant difference FLSD at 5% probability level. Graphical plots showing the
relationships between the selected soil properties and for the different land use history
was carried out

Results and Discussions
Soil aggregates measured by percent mean weight diameter, (MWD %) were highly
stable in the rubber plantation soil, this may be attributed to high litter accumulation in
the rubber plantation soil and these leaves contain latex which improved the stability of
soil aggregates and increased the organic matter level of the soil, this observation is
supported by the reports of Krull (2004), who also observed that as organic matter
increased, aggregate stability also increased. (Table 1).
Table 1: Physicochemical properties of plantation soils with depth

<table>
<thead>
<tr>
<th>Plantation type</th>
<th>Depth of Sampling (cm)</th>
<th>Sand/clay ratio</th>
<th>Organic Matter (%)</th>
<th>Aggregate Stability (%)</th>
<th>Exchangeable Sodium percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rubber</td>
<td>0-15</td>
<td>1.13</td>
<td>5.34</td>
<td>0.72</td>
<td>2.03</td>
</tr>
<tr>
<td>Rubber</td>
<td>15-30</td>
<td>0.72</td>
<td>2.36</td>
<td>0.8</td>
<td>1.58</td>
</tr>
<tr>
<td>Pineapple</td>
<td>0-15</td>
<td>1.94</td>
<td>2.34</td>
<td>0.26</td>
<td>4.31</td>
</tr>
<tr>
<td>Pineapple</td>
<td>15-30</td>
<td>1.68</td>
<td>1.71</td>
<td>0.28</td>
<td>3.88</td>
</tr>
<tr>
<td>Oil palm</td>
<td>0-15</td>
<td>0.89</td>
<td>5.09</td>
<td>0.44</td>
<td>3.47</td>
</tr>
<tr>
<td>Oil palm</td>
<td>15-30</td>
<td>0.52</td>
<td>3.89</td>
<td>0.29</td>
<td>4.66</td>
</tr>
<tr>
<td>FLSD (0.05)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>0.32</td>
<td>0.79</td>
<td>0.25</td>
<td>1.7</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>0.26</td>
<td>0.65</td>
<td>N.S</td>
<td>N.S</td>
<td></td>
</tr>
<tr>
<td>PXD</td>
<td>N.S</td>
<td>1.12</td>
<td>0.35</td>
<td>N.S</td>
<td></td>
</tr>
</tbody>
</table>

Generally for all the plantation type studied, aggregate stability was seen to decrease with depth except in the pineapple plantation soil. This may be due to the fact that the pineapple soils were mostly sandy (pineapple thrives well in well drained sandy soils). This observation also supports the report that organic matter had a strong relationship with the sand/clay ratio, as organic matter additions increased aggregation regardless of cation composition, as observed in this study (Figure 1), this observation agrees with an earlier report of Aldrich and Martin, (1954).

The pineapple soils had the highest sand/clay ratio which reduced with depth in all the plantations sites considered. The high sand/clay ratio in the pineapple soil probably led to a low aggregate stability, this was also reported in a study by Kay and Angers, (1999) suggesting that clay content in the soil affected its aggregate stability. These observations therefore supports the inverse relationship between sand/clay and aggregate stability observed in this study (Figure 1), as an increase in sand/clay ratio led to a decrease in the aggregate stability in all the plantations considered. The exchangeable sodium percentage was highest in the oil palm within the 15-30cm depth. This may be due to the high percentage of sodium in the exchange site relative to other exchangeable cations. The exchangeable sodium percentage of soils decreased with depth except in oil palm soil where it increased with depth. There was an inverse relationship between the exchangeable sodium percentage and the aggregate stability (Figure 1), this observation is supported by the report of Aldrich and Martin, (1954) that, as aggregate stability decreases the exchangeable sodium percentage increases.
Summary and Conclusion

The results from this study showed that soils from the pineapple orchard had low aggregate stability and a high sand/clay ratio and by implication the water retention capacity and the yield in the Pineapple orchard of the Michael Okpara University of Agriculture, Umudike may be affected. The study also established a relationship between aggregate stability, sand: clay ratio and exchangeable percentage, results showed an inverse relationship between aggregate stability and sand clay ratios of the plantation soil but direct relationship between OM and ESP of the studied soils, however the ESP explained to a greater degree ($r^2 = 62\%$) the relationship between the soil properties in pineapple rubber and palm plantation soils, therefore improvement of exchangeable sodium percentage in the plantation soils in Michael Okpara University of Agriculture, would lead to sustainable productivity of these plantation crops since it has a high degree effect on other soil properties.

![Graph](image_url)

Fig 1: Relationship between sand:clay, OM, ESP and MWD of soils from different plantation sites

References


