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# Fertility Assessment of Nun River Floodplain Soils in Bayelsa State, Southern Nigeria for Agricultural Productivity

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**ABSTRACT:** *Following massive crude oil exploitation in Bayelsa State, arable land is shrinking and a food crisis, looming. To stop this trend, information on soil fertility status and management strategies becomes important for policy development. This paper assesses fertility status of the Nun River floodplain soils in Bayelsa State using newly developed indices for sustainable agricultural productivity and food security. Nun River plain alluvial soils of different landforms were collected from the genetic horizons of nine profiles, and analysed for physicochemical characteristics and soil fertility assessed using soil fertility index. (SFI) and soil evaluation factor (SEF). ). Silt-sized particles dominated Odi (ODI), Koroama (KRM) and Niger Delta University (NDU 1) soils, except in NDU2 and NDU3, pH was moderate to slightly acidic (5.64–6.30), available P, low to high (0.6–22 mg/kg), organic C (0.31–5.35%), and total nitrogen (0.01–0.45%) low to high while calcium dominated the exchange complex. Correlation between Organic matter and total N ($r = 0.366, p < 0.001$) and available P ($r = - 0.310, p < 0.01$) was highly positively, suggesting that organic matter dictates availability of N and P. The SFI values were higher ($p < 0.05$) than SEF except in NUD2 and NDU3, pH, organic matter and available phosphorus contributing more. Of paramount importance is conservation of organic matter as the accumulation of biomass greatly improved physical properties and fertility of the soil.*
**KEYWORDS**: Soil fertility assessment, Soil evaluation factor, Soil fertility index, Nun River floodplain, Bayelsa State

## INTRODUCTION

Tropical forests are one of the most productive of all terrestrial ecosystems and play a functional role in maintaining biodiversity, improving the global climate and conserving soil (ITTO, 2020). But, in the Niger Delta region of Nigeria, the amount of land available for agricultural production continue declining following the discovery and exploitation of crude oil (Dickson and Dadiovei, 2010). With increasing oil revenues, little or no attention was paid to protecting land for agricultural production. Oil companies went about their business with little or no effort. Given the degradation of land for agricultural production, exploration and exploitation activities have neither taken this into account nor protected the limited well-drained land available for agriculture (UNDP, 2006). With the increasing loss of agricultural land to the oil industry, food crises have become inevitable and worsened, recently. Therefore, information on the soils of this region, especially in terms of soil fertility, is needed to help policy makers, farmers and governments at various levels, understand the need to conserve agricultural resources and possible management strategies. And the soils in the Niger Delta region are classified as alluvial or wet soils.

Adeniran and Babatunde (2010) describe wetlands as permanently or seasonally flooded lowlands along rivers or valley bottoms with high water tables. Wetlands are among the most important ecosystems (Ernest and Onweremadu, 2016). Important wetlands in Nigeria include Hideja and Kirikasamu, Lake Chad, Komduge, Yobe, Lake Kanji, Bathuria, Adiami-Nguru floodplains, Matgadra-Kabok floodplains, Niger Delta floodplains and coastal lagoons near Lagos and the delta o Cross River. Alluvial soils originate from alluvial deposits in the floodplains of large rivers. They are characterized by a light texture and an unstable water balance due to high levels of groundwater and precipitation. One of the characteristic features of alluvial soils is stratification, the alternation of soil layers and layers of new materials (Dengiz, 2010), which leads to changes in the properties of alluvial soils from one region to another or from "one place to another" (Dengiz, 2010)., 2006). Therefore, highly productive alluvial soils often show large differences in their properties over short distances. But, the agricultural productivity of soils depend on the fertility status and whether or not the crops grown can withstand the perceived limitations of the soil in that environment (Dixon, 2021). This highlights the need to understand soil properties through gathering scientific environmental data to ensure good soil health. This paper investigates soil fertility of the Nun River floodplain using SFI and SEF to maintain good soil health.

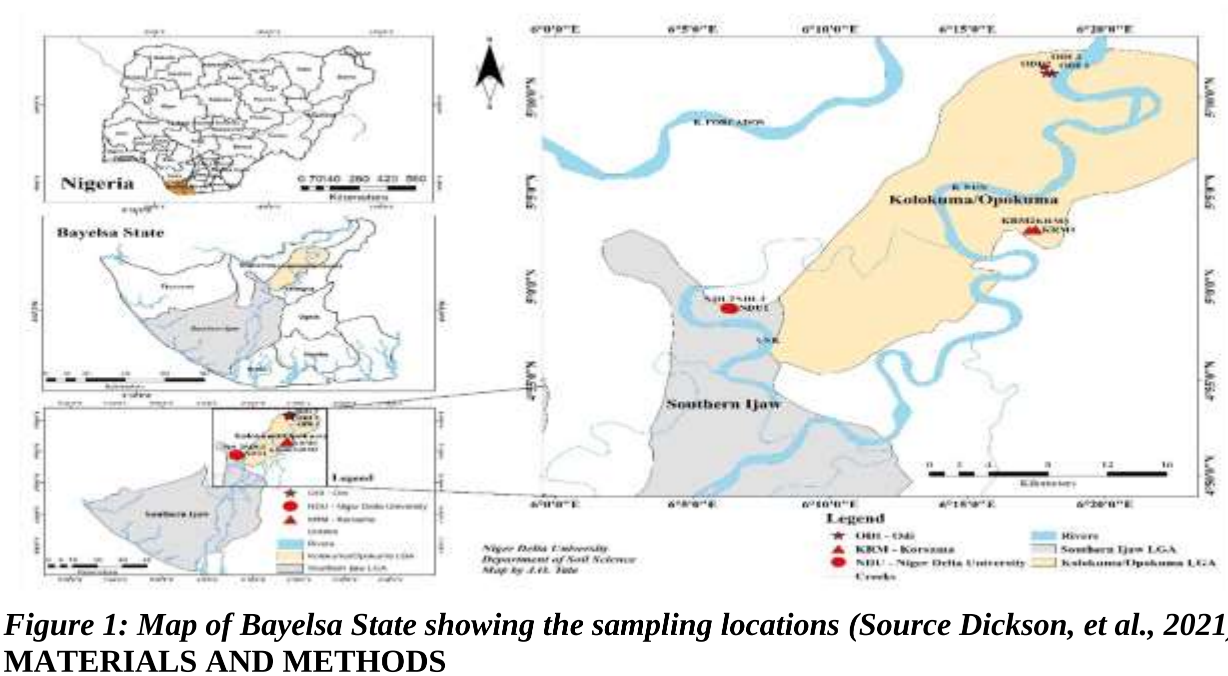


*Figure 1: Map of Bayelsa State showing the sampling locations (Source Dickson, et al., 2021)*

## MATERIALS AND METHODS

### Description of the Study Areas, Soil Sampling, Analyses and Statistical Analyses

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The study area lies between 05°22'03.9"N and 04°59'08.9"N and 006°30'21.1"E and 006°06'54.1"E, located in Bayelsa state, Southern Nigeria which have been extensively reported by Dickson et al. (2021). The Soil Mapping Unit (SMU) designations were ODI1, ODI 2, ODI3 for Odi, KRM1, KRM2, KRM3 for Koroama Soils and NDU1, NDU2, NDU3 for the Niger Delta University Teaching and Research Farm. Other details including soil sampling procedures and analytical methods and statistical analysis were as reported in Dickson et al. (2021).

## RESULTS AND DISCUSSIONS

### Physico-chemical properties of the Soils

### Physical Properties of the Soils

In ODI and KRM soils, silt-sized particles dominated, followed by sand and then clay, while in NDU, silt-sized particles also dominated followed by clay and then sand (Figure 2). Silt was found to be high in the surface and subsurface layers of all pedons. Variations in soil texture have been attributed to differences in parent material and topography (Abua, 2012). The textural class distribution in Odi soils showed no significant differences, meaning that the chemical and physical properties of the parent materials were not significantly different (Dickson, et al., 2021). Silt was rated high in the surface and subsurface layers of all pedons, sand, low to moderate in the surface layers of KRM2 and KRM3, and clay low to moderate in the surface and subsurface layers of KRM2 and KRM3 based on Hazelton Murphy (2007) rating. Similarly, silt is classed high in all layers of all pedons, clay low to moderate in the upper and lower layers of NDU1 and NDU2 and low in NDU3. Sand is classified as low in all pedons. Since the mud concentration in the upper and lower soil layers of all pedons is greater than 50%, the soils may have strong surface cohesion and have properties that resist the risk of erosion (Dickson et al., 2021). Abua (2012) report indicated that soils with silt content above 15% in the topsoil and subsoil are indicative of soils with high surface consolidation and such soils may not be prone to erosion risk. Given the silt content of these soils, therefore, the studied soils (ODI, Koroama and Niger Delta University) have high surface consolidation and may not be prone to erosion risk.

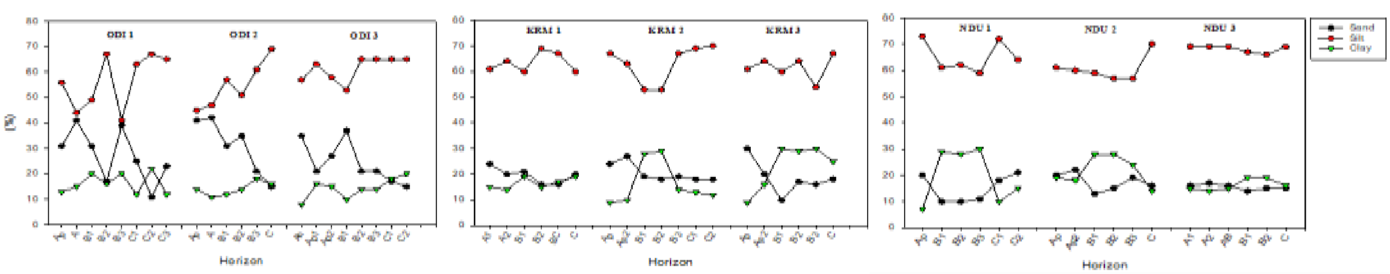


***Figure 2: Percent sand, silt and clay in Odi, Koroama and Niger Delta University Soils (source: Dickson, 2018)***

**Chemical Properties of the Soils**

On Figures 3 4, and5 are presented the chemical properties of the soils. In the surface layers, pH value varied between 5.64 and 6.30 and between 5.99 and 6.30 in the subsurface layers. Available P (mg/kg) varied from 6 to 21 in ODI soils, 4 to 22 in KRM soils, and 0.6 to 11 in NDU soils (Figure 3). For organic C ODI soils, it was 0.11–5.26%, 0.31–1.84% in KRM soils, and 0.93–2.81% in NDU soils while total N content was 0.03–0.45%, 0.02–0.11%, and 0.02–0.22%, respectively (Figure 4).

The pH of the soils was within moderately acid to neutral classes (Figure 3) according to FPDD (2012) categorization. FPDD categorized Bayelsa State soils into the following pH classes: between 5.0 – 5.5 strongly acid, 5.6 -6.0, moderately acid, 6.0 – 6.5 slightly acid, 6.6-7.2 neutral and 7.3-7.8 slightly alkaline. Following the categorization, the topsoil layers of NDU3 (5.42) and the subsurface layers of KRM3 (5.48) were strongly acid while the remaining soils (surface layers of ODI1, ODI2, ODI3, KRM1, KRM2, KRM3, NDU1 and NDU2 as well as the subsurface layers of ODI1, ODI2, ODI3, KRM1, KRM2, NDU1, NDU2 and NDU3) were slightly acid to neutral. Since the preferred range by Brady and Weil (2007) for most crops is 5.5 to 7.0, as this pH range is optimal for the overall satisfactory availability of plant nutrients, the pH of the soils is suitable for most crops

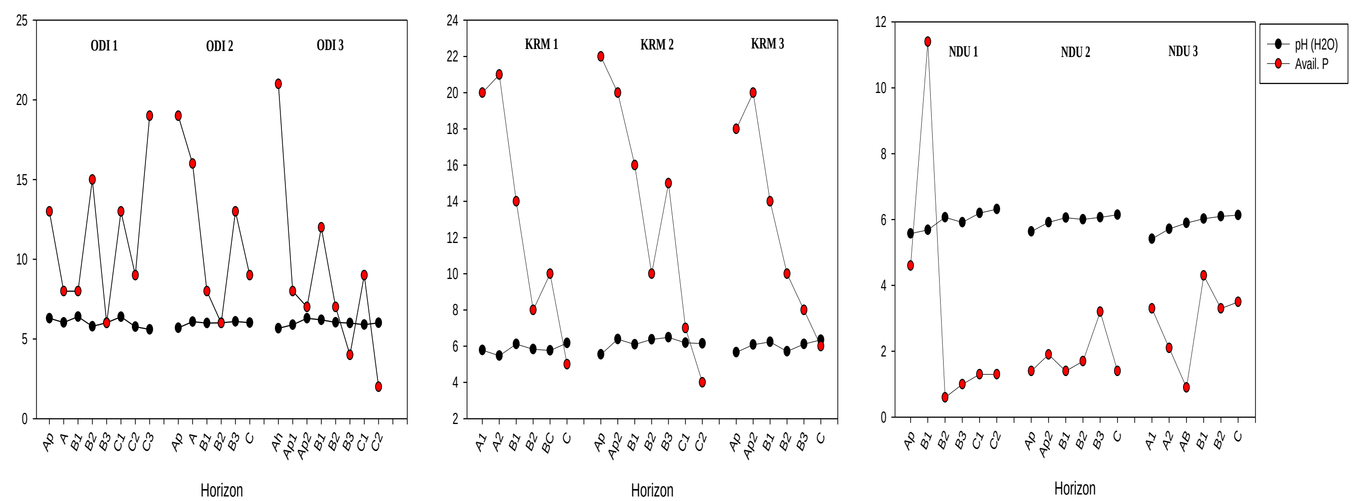


***Figure 3: pH and available P in Odi, Koroama and Niger Delta University Soils (source: Dickson, 2018)***

Also, available P concentration decreased with increased profile depth in the ODI and KRM which portrayed close relationship between organic matter and available P but in the case of NDU soils, it was different (Figure 3). Organic matter was identified as the principal source of soil P for many soils (McCauley et al., 2017). Available P level in NDU1, NDU2 and NDU3 was low which is attributed to high exchangeable acidity in comparison to total exchangeable bases. Organic matter content was positively related to available P as both of them decreased with increasing depth, indicating that P decrease was due to decreasing concentration of organic matter with depth. FPDD (2012) rating for available P (Bray-1-P) for Bayelsa soils was ‹3-very low, 3-7 low, 7-20 moderate and ›20 high. Based on the FPDD ratings, available P level in the ODI and KRM generally, was moderate while NDU was low. Distribution of P showed no regular pattern which corroborated Nuga et al. (2006) and which was attributed to P fixing capacity and slow release resulting from the relatively high level of iron and aluminium oxides in the soils. Low P availability in tropical soils attributed to the nature of the chemical forms of soil P and the high content of oxides of Fe and Al which are associated with high P fixation (Dickson et al., 2021). Consequently, P is likely to be one of the most limiting nutrients for crop production in the soils

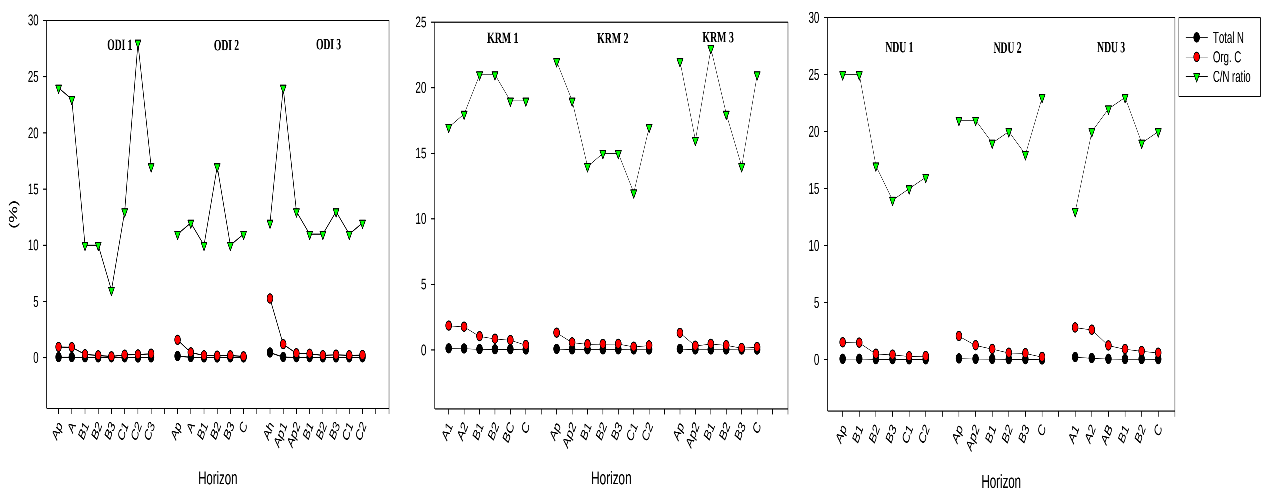


***Figure 4: Total organic carbon, nitrogen and C/N ratio in Odi, Koroama and Niger Delta University soil (source: Dickson, 2018)***

The organic C in the surface 40 cm of the soil forming units was 0.95% in ODI1, 0.46 to 1.58% in ODI2, 0.38 to 5.25% in ODI3, 1.76 to 1.84% in KRM1, 0.43 to 1.30% in KRM2, 0.31 to 1.29% in KRM3, 1.48 to 1.51% in NDU1, 0.93 to 2.06% in NDU2 and 1.23 to 2.81% in NDU3. Organic carbon concentration in the soils decreased irregularly with increase in soil depth which agreed with the findings of Dickson et al. (2021), Atofarati *et al* (2012) and Idoga and Azagaku (2005) in Nigeria. High soil organic matter concentration in surface horizons decreasing with increasing soil depth could be ascribed to low biomass return to the soil, especially during the short fallow periods coupled with bush burning, a cultural practice that destroy organic materials that should return to the soil. Like organic C, total N concentration in the profiles decreased with increase in depth (Figure 4) revealing that organic matter is the main source of total N as earlier established by Adeyanju (bush burning 2005). The highest total N content (0.45%) value was recorded in the surface layer of ODI3 designated 'Ah', which recorded the highest organic C content (5.25%). Total N content in all locations were higher in the surface soil layers than the underlying layers, which was attributed to surface higher organic C content. The higher total N content in the layer underlying the surface layer of ODN2 may be attributed to frequent burning of crop residues coupled with long-term cultivation which accelerated the rapid turnover rates of organic materials.

Exchangeable bases (Ca, Mg, K and Na) as presented in figure 5 indicated that $Ca^{++}$ dominated the exchange complex. On the basis of FAO (2006) ratings for $Ca^{++}$ and $Mg^{++}$, surface 40 cm and subsurface exchangeable $Ca^{++}$ was very low while exchangeable $Mg^{++}$ contents were low to medium. Low exchangeable bases in soils have been attributed to acidifying properties of organic matter, high aluminium concentration and leaching loss of exchangeable bases (Tisdale et al., 2008). In these soils, low exchangeable Ca and Mg was attributed to lack of ferromagnesian minerals, low nutrient retentive capacity, high exchangeable Al and Fe as well as leaching loss of the nutrients owing to excessive rainfall. The X-ray diffraction results reported by Dickson (2018) on these soils indicated that these soils were low in ferromagnesian minerals. Biotite and vermiculite were the only ferromagnesian minerals and their concentrations were low. Biotite was found in low concentrations in KRM1 only while vermiculite was detected in all the samples though in small concentrations. The near absence or low concentration of the ferromagnesian group of minerals which are known to supply Ca and Mg to soils probably was the main reason for the low levels of these nutrients.

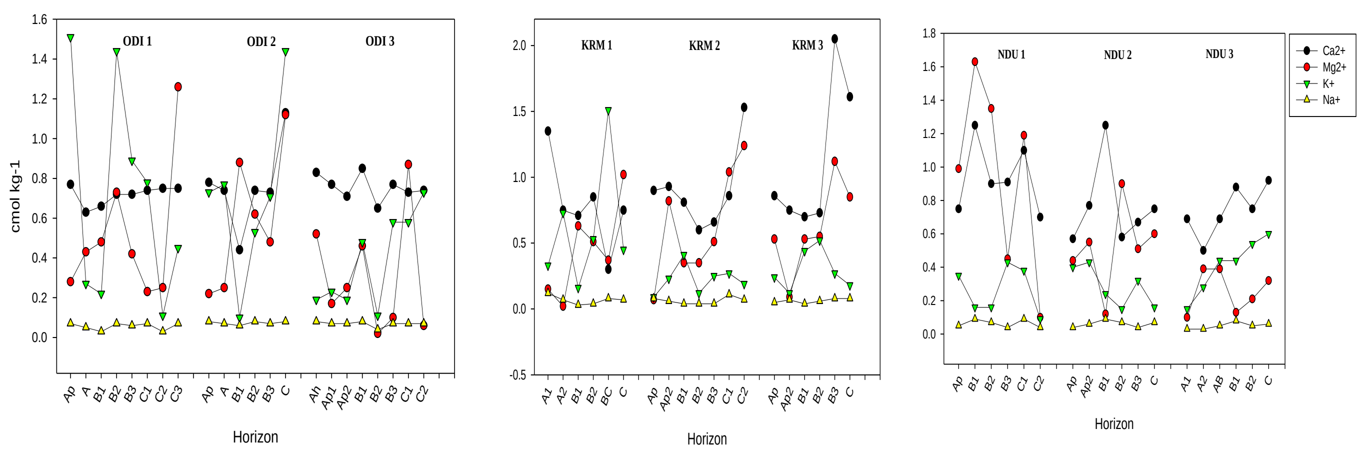


***Figure 5: Exchangeable $Ca^{2+}$, $Mg^{2+}$, $K_+$, and $Na^+$ in Odi, Koroama and Niger Delta University***
***Figure 5: $Ca^{2+}$, $Mg^{2+}$, $K^+$ and $Na^+$ in Odi, Koroama and Niger Delta University Soils***

Exchangeable K (Figure 5) unlike exchangeable Ca and Mg varied from low to very high (FAO, 2006; FPDD, 2012). Most of the values were within medium to very high ratings showing there is sufficient K for crop growth. This conformed with the common to many and/or abundant mica flakes observed during field sampling. Based on FAO (2006), rating for exchangeable K, soils with exchangeable K greater than 1.2 is very high, 1.2 - 0.6 high, 0.6 – 0.3 medium, 0.3 - 0.2 low and less than 0.2 very low.

The K concentrations in most of the KRM and NDU soils further away from the Niger River were low to medium while ODI soils closer to the Niger River were medium to high. This development is difficult to explain as mica flakes presence was recorded in all the profile pits. This development might be attributed to lack of ferromagnesian minerals in the soils. The low to moderate K in KRM and NDU soils night be due to the presence of muscovite as dominant clay mineral over biotite in the soils. However, some level of variation in the distribution of basic cations down the profiles was observed which is attributed to differences in the source of the alluvial materials that formed the horizons rather than movement of nutrients from the top to the lower horizons since these soils were young and no marked clay illuviation.

**Relationship between some of the soil properties**

The fact that weathering of the silt fraction contributes to the clay fraction is indicated by the positive relationship between silt and clay while the sand fraction contributed nothing. This relationship also suggests that both soil textural classes were influenced by similar climatic, pedogenetic and biotic factors while the reverse sand. Furthermore, since clay is negatively charged, clay contributed positively to exchangeable acidity, Al and ECEC, hence the significant positive correlation between clay and these properties ($r = 0.332$, $p < 0.01$; $r = 0.246$, $p < 0.01$; $r=0.359$, $p<0.1$ respectively). Earlier, Angélica et al. (2012) reported that negatively charged sites of clay bonded Al cations which helps to reduce exchangeable Al cations saturation. Clay had inverse significant negative relationship available P ($r = -0.216$, $p < 0.05$), indicating that clay contributed negatively to P availability. It is possible that aluminum and Fe, which are part of the clay structure fix the P in these soils. Correlation between organic matter and total nitrogen had highly significant positive relationship ($r = 0.366$, $p < 0.001$), indicating that the total soil N was a function of the amount of organic matter present. Deekor et al. (2012) recorded similar results for Odukpani soils in Cross River State, southern Nigeria. According to Dickson et al. (2021), the higher the organic matter, the greater the chance of nitrogen entering the soil as organic matter and total nitrogen mainly come from the accumulation of biomass in soil. Organic matter correlation with available P was positive and highly significant ($r = -0.310$, $p < 0.01$), suggesting that organic matter contributed positively to P accumulation and availability (Dickson et al., 2021).

**Table 1: Pearson's Correlation matrix of soil properties (source: Dickson, 2018)**

| | pH-H₂0 | ECe | T-N | Org. C | Org. M | P | Ca | Mg | K | Na | TEB | Acidity | Al | ECEC | Al sat | BS | Sand | Silt | Clay |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH-H₂0 | 1.000 | | | | | | | | | | | | | | | | | | |
| ECe | | 1.000 | | | | | | | | | | | | | | | | | |
| T-N | -0.224* | 0.325** | 1.000 | | | | | | | | | | | | | | | | |
| Org. C | -0.307** | 0.366*** | 0.924*** | 1.000 | | | | | | | | | | | | | | | |
| Org. M | -0.307** | 0.366*** | 0.924*** | | 1.000 | | | | | | | | | | | | | | |
| P | | | 0.326** | 0.310** | 0.310** | 1.000 | | | | | | | | | | | | | |
| Ca | | | | | | | 1.000 | | | | | | | | | | | | |
| Mg | | | | | | | 0.223* | 1.000 | | | | | | | | | | | |
| K | | | | | | | | | 1.000 | | | | | | | | | | |
| Na | | | | | | | 0.506*** | 0.219* | 0.248** | 1.000 | | | | | | | | | |
| TEB | | | | | | | 0.579*** | 0.650*** | 0.644*** | 0.523*** | 1.000 | | | | | | | | |
| Acidity | | | | | | | | | | | | 1.000 | | | | | | | |
| Al | | | | | | | | | | | | 0.927*** | 1.000 | | | | | | |
| ECEC | | | | | | | 0.250** | 0.416*** | 0.322** | | 0.518*** | 0.812*** | 0.757*** | 1.000 | | | | | |
| Al salt | | | | | | | -0.278** | -0.264** | -0.335** | -0.307** | -0.482*** | 0.651*** | 0.809*** | 0.267** | 1.000 | | | | |
| BS | | | | -0.198* | -0.198* | | 0.399*** | 0.316** | 0.341** | 0.397*** | 0.565*** | -0.775*** | -0.689*** | -0.343** | -0.731*** | 1.000 | | | |
| Sand | | -0.179* | | | | | | | | | | -0.178* | | | | 0.191* | 1.000 | | |
| Silt | | 0.208* | | | | | | | | | | | | | | | -0.942*** | 1.000 | |
| Clay | | | | | | -0.216* | | | | | | 0.332** | 0.246** | 0.350*** | 0.073 | -0.263** | -0.675*** | 0.396*** | 1.000 |

*. Correlation significant at 5% level, **. Correlation significant at 1% level, *** Correlation significant at 0.1% level

**Fertility status of the soils using SFI and SEF**

On Figures 6 through 8 is a graphical representation of the comparison between SFI and SEF of the soil mapping units. When compared with Turkish t-test, the mean SFI values were higher significantly ($p < 0.05$) than SEF values in the pedons except NUD2 and NDU3 (Table 2). The ODI3 surface layer recorded the highest SFI value (35.56) while the bottom layer of NDU2 recorded the lowest value (7.66). Similarly, the highest SEF value (15.50) occurred in the surface layer of ODI3 while the lowest (5.07) was in the subsurface layer of ODI3. When t-test for the paired samples of SFI and SEF were compared for ODI1, ODI2, ODI3, KRM1, KRM2, KRM3, and NDU1. They were significant at the 5% probability level while NDU2 and NDU3 were not significant.

**Table2: t-test statistic for paired sample for SFI and SEF (source: Dickson, 2018)**

| Soil Mapping Unit | Mean SFI | Mean SEF | t-statistic |
|---|---|---|---|
| ODI1 | 19.03 | 6.17 | 8.43* |
| ODI2 | 19.64 | 6.16 | 7.55* |
| ODI3 | 16.60 | 15.50 | 5.10* |
| KRM1 | 21.89 | 7.76 | 5.57* |
| KRM2 | 21.89 | 7.76 | 5.57* |
| KRM3 | 20.71 | 6.17 | 7.25* |
| NDU1 | 11.53 | 7.58 | 3.67* |
| NDU2 | 9.17 | 7.01 | $5.35^{ns}$ |
| NDU3 | 11.65 | 7.48 | $8.10^{ns}$ |

* t-test significant at 5% level, $^{ns}$ not significant(source: Dickson, 2018)

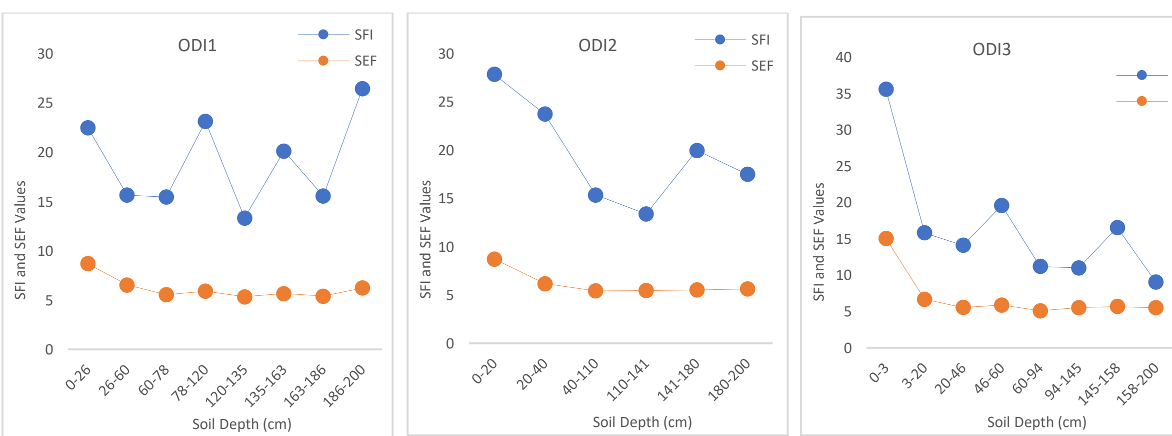


***Figure 6: Comparison of SFI and SEF with Depth in Odi Soils (source: Dickson, 2018)***

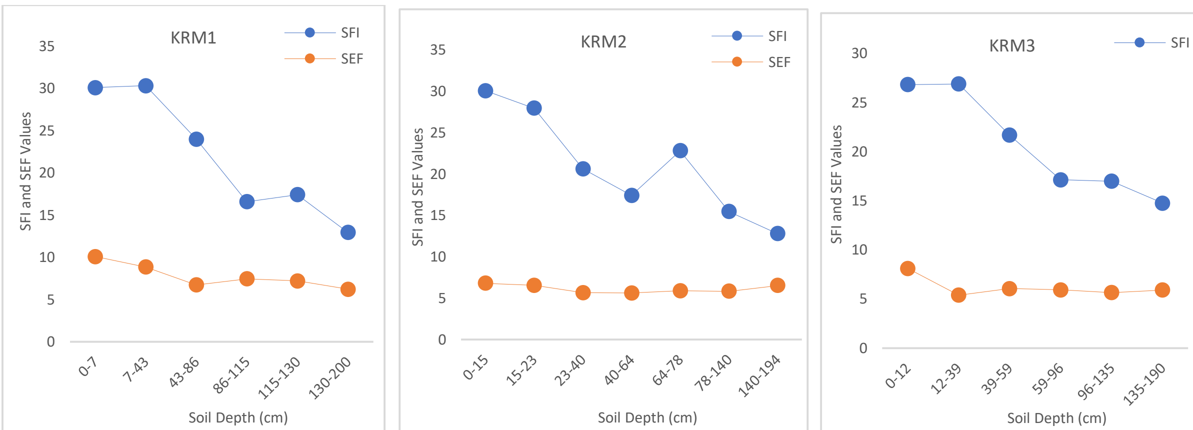


***Figure 7: Comparison of SFI and SEF with Depth in Koroama Soils (source: Dickson, 2018) .***

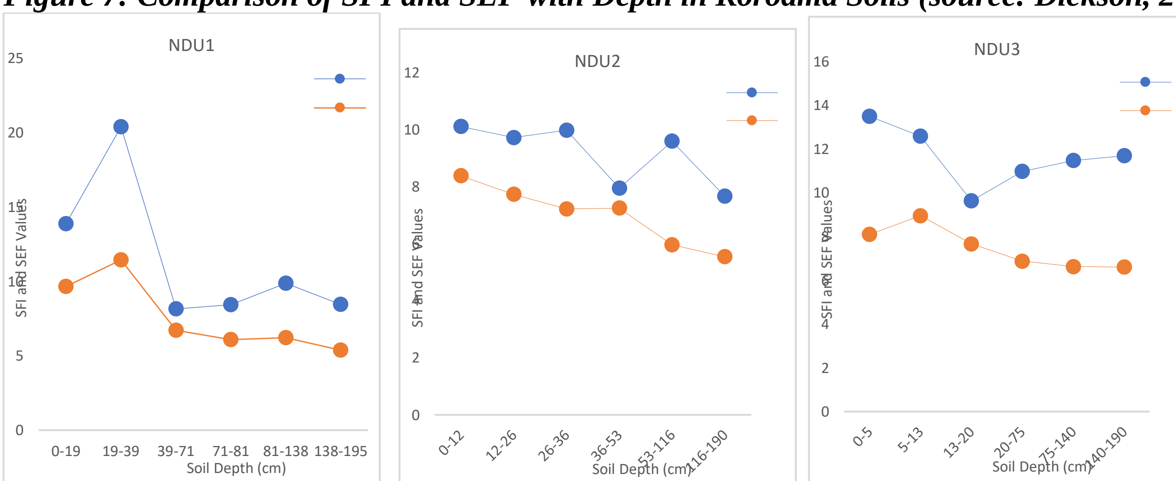


***Figure 8: Comparison of SFI and SEF with Depth in Niger Delta University Soils (source: Dickson, 2018)***

The SFI values in the soil were higher than the SEF values, mainly based on pH, organic matter and phosphorus. Apart from ODI1 that recorded higher SFI values in the lower layers, SFI values decreased with increasing depth in all map units. The higher SFI values in the lower layers of ODI1 was due to the higher P content and relatively high organic matter content. Similarly, SEF values decreased with increasing soil depth map units, attributed to higher soil nutrient content. The SFI values reported by Akbar et al. (2010) and Aiza et al. (2013) in Malaysia were higher. Akbar et al. (2010) attributed the higher SEF values to the high organic matter and nutrient content of the "Resam" vegetation covering the surface. Aïza et al. (2013) recorded the highest SEF value in soil with high organic matter and low exchangeable Al content. Also recorded was SEF values of less than 5 in restored forests and secondary forests which Lu et al. (2002) considered very poor in terms of soil fertility. All horizons in this study recorded SEF values greater than 5 (Figures 6-

8) and using the standard of Lu et al. (2002), the soils were considered fertile. This is understandable because all profile pits were situated in fallow areas

## CONCLUSION

SFI values in the Nun River floodplain were significantly higher than SEF values for all pedons except NUD2 and NDU3 ($p < 0.05$). SFI and SEF values in all map units decreased with increasing soil depth, except in ODI 1 where soil layers recorded higher SFI values. The higher SFI values in the lower layers were due to the higher P content and relatively high organic matter content. Correlation results between organic matter and total nitrogen content and available P showed that organic matter had a positive effect on nitrogen and P accumulation and availability. The accumulation of biomass contributes to improving soil fertility and the physical structure of the soil. Therefore, soil organic matter must be conserved to maintain sustainable soil health.

## REFERENCES

Abua, M.A. 2012. A Comparative Analysis of Morphological and Physico-Chemical Characteristics of Soils of Southern Cross Rivers State – Nigeria. Global Journal of Human Social Science, Geography & Environment, Geosciences 12:55-60.

Adeniran, K.A., and Babatunde, O.O. 2010. Investigation of wetland soil properties affecting optimum soil cultivation. *Journal of engineering science and technology review*. 3(1): 23-26.

Aiza, S.J., Arifin, A., Hazandy, A., Mohd, H.A., Trevor, S.B., Shamshuddin, J. & Nik, M.M. 2013. Assessing Soil Fertility Status of Rehabilitated Degraded Tropical Rainforest. American Journal of Environmental Science 9:280-291.

Akbar, M.H., Ahmed, O.H., Jamaluddin, A.S., Majid, N.M. & Abdul-Hamid, H. 2010. Differences in soil physical and chemical properties of rehabilitated and secondary forests. American Journal of Applied Science 7:1200-1209.

Akpan-Idiok, A.U. & Ogbaji, P.O. 2013. Characterisation and Classification of Onwu River Floodplain Soils in Cross River State, Nigeria. International Journal of Agricultural Research 8:107-122.

Alemayehu, Y., Gebrekidan, H. & Beyene, S. 2014. Pedological characteristics and classification of soils along landscapes at Abobo, Southwestern lowlands of Ethiopia. Journal of Soil Science and Environmental Management 5:72-82.

Anderson, J.M. & Ingram, J.S.I. 1993. Tropical Soil Biology: A handbook of methods., CBA International.

Angelica, B.C., Castillo, R.F.D., Etchevers-Barra, J.D., Guttierrez-Castorena, M.D.C. & Baez, A. 2012. Selection and interpretation of soil quality indicators for forest recovery after clearing of a tropical montane cloud forest in Mexico. Forest Ecology and Management 277:74-80.

Arifin,A.S., Tanaka, S., Jusop, S. Majid, N.M. & Ibrahim, Z. 2008a. assessment on soil fertility status and growth performance of planted dipterocarp species in Perak, Peninsular Malaysia. Journal of Applied Science 8:3795-3805.Bohn, H., Michael, B. L. & O'Connor, G. A. 2001. *Soil Chemistry,* New York, John Wiley & Sons.

Brady, N.C. & Weil R.R. 2005. The Nature and Properties of Soils. Pearson Princeton Hills

Bray, R.H. & Kurtz, L.T. 1945. Determination of total, organic and available forms of phosphorus in soils. Soil Science 59:39-45.

Chude, V.O. 2012. Literature Review on the Soil Fertility Investigation in Southern Nigeria. Federal Ministry of Agriculture and Rural Development. 2nd Ed. Abuja.

Day, P.R. 1965. Particle fractionation and particle size analysis. American Society of Agronomy, Madison, Wisconsin, pp 545-567.

De Wit, H.A. Eldhuset, T.D. & Mulder, 2010. Dissolved Al reduces Mg uptake in Norway space forest; Results from a long-term field manipulation experiment in Norway. Journal of Forest Ecology Management 259:2072-2082.

Deekor, T.N., Iwara, A. I., Ogundele, F.O., Amiolemen, S.O. & Ita, A.E. 2012. Changes in Soil Properties under different Land Use covers in parts of Odukpani, Cross Rivers State, Nigeria. Journal of Environmental Ecology 3:86-99.

Dengiz, O. 2010. Morphology, Physico-Chemical Properties and Classification of Soils of the Tigris River in the South-east Anatolia Region of Turkey. *Journal of Agricultural Sciences* 16:205-212.

Dengiz, O., Gol, C., Karaca, S & Yuksel, M. 2006. Effects of different landscape position and material on soil variability and land use in both sides of Acicay River-Cankiri. Soil Meeting on Soil Sustaining Life on Earth, Mapping Soil and Technology Proceedings Vol. II, 745-751, Sanlurfa Tuckey.

Dickson, A.A. & Dadiowei T.E. 2010. Impact Mitigation Monitoring as an Environmental Conflict Management Tool: The Gbaran-Ubie Integrated Oil and Gas Project Experience In: Dynamics of Peace Processes Albert, I.O. & Oloyede I.O. eds. Centre for Peace and Strategic Studies, University of Ilorin, Ilorin. 465-486p.

Dickson, A.A. 2018. Characterization, classification and suitability evaluation of agricultural soils of selected communities located along various river systems in Bayelsa State, Southern Nigeria. Ph.D. Thesis Department of Agronomy, North West University Mafikeng Campus, South Africa. Unpublished. 324p.

[6] Dickson, A.A., Tate, J.O., Ogboin, T.P., Cameroon, P.O. William, AP. 2021. Spatial variability of selected soil properties of the lower Niger River floodplain soils in Bayelsa State, Nigeria. *African Journal of Agriculture and Food Science* 4(3):14-27.

Dickson, A.A., Tate, O.J., Kamalu, O.J. & Ogboin, T.P. 2021 Characterization and Classification of some lower Niger Alluvial Soils in Bayelsa State, Nigeria. *Bulgarian Journal of Soil Science, Biochemistry and Ecology* 55(3-5)

Egbuchua, C.N. & Ojobor, S. 2011. Characterization of some hydric soils in the Niger Delta region of Nigeria for land evaluation purposes. International journal of Applied Biological Research 1:77-82.

Ernest, C.I. & Onweremadu, E.U.J. 2016. Classification of soils along Ogochie River Floodplain in Niger-Okpala, Imo State, Southeastern Nigeria. Journal of Global Research 2:78-83.

Estafan, G., Sommer, R. & Ryan, J. 2013. Methods of Soil, Plant and Water Analysis: A Manual for the West Asia and North Africa. International Center for Agricultural Research in the Dry Areas (ICARDA).

FAO, 2006. Guidelines for soil description. 4th edition. Rome, Italy: Food and Agricultural Organisation.

Fageria, N.K. & Baligar, V.C. 2008. Ameliorating Soil Acidity of Tropical Oxisols by Liming for Sustainable Crop Production. Advances in Agronomy. Elsevier INnc.

Fasina, A.S. 2008. Irrigation Suitability Evaluation of Asa River Basin Soils, Southeastern Nigeria. International Journal of Soil Science 3:35-41.

Hartz, Y. 2007. Soil Testing for Nutrient Availability. Procedures and Interpretation for California Vegetable Crop Production. University of California, Davis. Department of Plant Sciences Vegetables Research and Information Center, 1-7.

Hazelton, P. & Murphy, B. 2007. Interpreting Soil Test Results. What do all the numbers mean? Australia, CSIRO Publishing.

Houba, V.J.G., Van Der Lee, J.I. &Novozamsky, I. 1995. Soil and Plant Analysis, part 5B soil analysis procedures, other procedures.

ITTO, 2020. Guidelines for Restoration, Management and Rehabilitation of Degraded and Secondary Tropical forests. ITTO. Policy development series 13. Yokohama, Japan. 140p

Kamprath, E.J. 1970. Soil Acidty and Liming in Sanchez, P,A. (ed.). A Review of Soil Research in Tropical Latin America. North Carolina USA. North Carolina Experimental Station

Karuiki, S.K., Zhang, H., Schroder, J.L., Edwards, J., Payton, M., Carver, B.F., Raun, W.R., Krenzer, E.G., 2007. Hard red wheat cultivar responses to a pH and aluminum concentration gradient. Agronomy 99, 88-98.

Knoepp, J.D., Coleman, D.C., Crossley, D.A. & Clark, J.S. 2000. Biological indices of soil quality: an ecosystem case study of their use. Forest Ecology and Management. 138:358-368.

Lu, D., Moran,.E., & Mausel, P. 2002. Linking Amazonian secondary succession forest growth to soil properties. Land Degradation and Development 13:331-343.

Ojanuga, A.G., Okusami, T.A., Lekwa, G., 2003. Wetland soils of Nigeria: status of knowledge and potentials., Soil Science Society of Nigeria Monograph Soil Science Society of Nigeria, Nigeria.

Papienik, S.K., Lindstrom, M.J., Schumacher, T.E., Schumacher, J., Amalo, D.D., Lobb, D.A., 2007. Characterization of soil pedons in a landscape affected by long-term tillage. . Tillage Res. 93:335-345.

Sanchez, P.A., 1976. Properties and Management of Soils in the Humid Tropics. John Wiley and Sons, USA.

Sanchez, P.A., Palm, C.A., Buol, S.W., 2003. Fertility capability soil classification: a tool to help assess soil quality in the tropics. . Geoderma 114, 157 – 185.

Soil Survey Staff, 2006. Soil Survey Manual (Complete Print friendly version) USDA National Resource Conservation service USA.

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Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development -UK

Sumner, M.E., Stewart, B.A., 1992. Soil Crusting: Chemical and Physical Processes. . 1st ed. Lewis Publishers, Boca Raton, .

Tan, K.H., 2005. Soil Sampling, Preparation and Analysis. 2nd ed. Taylor and Francis, Boca Ranton. ISBN-10:0849334993, pp:623.

Tisdale, S.L., Nelson, W.L., Beaton, J.D. and Havlin, J.L. 2004. Soil Fertility and Fertilizers. 5$^{th}$ ed. Prentice Hall of India private Limited, New Delhi, India.

Hartz, T. 2007. Soil Testing for Nutrient Availability Procedures and Interpretation for California Vegetable Crop Production. University of California, Davis. Department of Plant Sciences. Vegetables Research and Information Center, 1-7.

Yetti, H., Arafin, A., Mohd, N.M., Hazandy, A., Shamshuddin, J., Nik, M.M., Ika, H., Leslie, A. and Khairulmazmi, A. 2011. Comparing the Fertility of Soils under *Khaya ivorensis* Plantation and Regenerated Degraded Secondary Forests. Am. J. Appl. Sci. 8 (5): 472-480.