African Journal of Agriculture and Food Science
ISSN: 2689-5331
Volume 7, Issue 2, 2024 (pp. 187-198)
www.abjournals.org

# NUTRIENT ASSESSMENT OF RAIN-FED LOWLAND AND UPLAND RICE PRODUCTION SYSTEMS IN OKIGWE, SOUTH-EASTERN NIGERIA

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**Cite this article:**

Ifeoma Monica Nwawuike (2024), Nutrient Assessment of Rain-Fed Lowland and Upland Rice Production Systems in Okigwe, South-Eastern Nigeria. African Journal of Agriculture and Food Science 7(2), 187-198. DOI: 10.52589/AJAFS-GI5TF3ZK

**Manuscript History**

Received: 18 Mar 2024

Accepted: 7 May 2024

Published: 13 Jun 2024



**ABSTRACT:** *The study was carried out to assess the nutrient status of the two major rice production systems (rain-fed lowland and upland) and the relationship among the nutrient contents of the soil in Okigwe area of Imo State, Nigeria. Soil samples from 15 cm depth were collected from 10 farms in the area: 5 farms from rain-fed lowland and 5 from upland rice production system. The soil samples were prepared and analyzed for macro and micro nutrients together with the particle size distribution. The results from the nutrient concentration in both rain-fed lowland and upland soils showed that pH favoured conditions for more availability of nutrients as seen in upland soils. The t-test results indicates a significant variation in % Clay (0.01*), % TS (0.008**), pH (0.0005**), TN (0.038*), available P (0.01*), Exchangeable Ca (0.03*) and Extractable B (0.02*). Correlation results showed TN as the major determinant of the other soil nutrients in both rain-fed lowland and upland rice production systems. In rain-fed lowland production system, TN correlated negatively and strongly with % TS (-0.81) and Cu (-0.70) with a weak negative association with Na (-0.57), K (-0.55), Mg (-0.50), available P (-0.57) and Fe (-0.64). In the upland rice production system, TN also had a negative association with many soil nutrients though some were weakly correlated while some were of strong association. They include Ca (-0.93), Mg (-0.65), Cu (-0.86), Mn (-0.69) and Zn (-0.76) with a positive association with Na (0.83) and pH (0.69). Despite TN being perceived as the major determinant of nutrients, OM in upland soils had a more positive association with other nutrients compared to that in the lowland soils. Hence, any management practices which will enhance nutrient status should be encouraged to help boost and sustain rice yield in both rain-fed lowland and upland rice production systems.*

**KEYWORDS:** Nutrient assessment, rain-fed lowland, upland rice, Okigwe.


Article DOI: 10.52589/AJAFS-GI5TF3ZK
DOI URL: https://doi.org/10.52589/AJAFS-GI5TF3ZK

## INTRODUCTION

Rice is one of the frontline commodities in world trade and a staple food for about 2.6 billion people in the world. Globally, the data on rice output showed that the Asian continent accounted for about 92%, America and the Caribbean accounted for 5% and 3% for Africa (Spore, 2005). In sub-Saharan Africa, West Africa is the leading producer and consumer of rice with 63.4% and 69.1% of total rice production and consumption respectively (WARDA, 2007). Three African countries are among the twentieth world highest producer of rice. Nigeria is the nineteenth highest producer of rice in world surpassed only by Egypt and Madagascar in Africa. It has been reported that Nigeria, Egypt and Madagascar produced 3218760, 4329500 and 4737970 metric tonnes of rice respectively (FAO 2010). In the entire continent of Africa, it is reported that only Egypt and Madagascar have attained self-sufficiency in local rice production, all other countries have rice demand exceeding local production (FAO, 2008).

In Nigeria, rice is one of the major staple foods (Adebisi et al., 2008). It is consumed across all geopolitical zones and socioeconomic classes in Nigeria. Rice growing environment in Nigeria are usually classified into four rice ecosystems namely: Rain-fed upland, Rain-fed lowland, Irrigated lowland, and Mangrove swamp (ATA, 2010). Rain-fed lowland is the most predominant rice production environment covering 47% of cultivated area and accounting for over 50% of the total rice produced in Nigeria, while rain-fed upland rice had 30% cultivated area with 17% domestic production. Irrigated systems, deep water and mangrove swamp environments covers only a small fraction of 23% cultivated area with 33% domestic production of rice production environments in Nigeria (KPMG, 2019). In Nigeria, about 6.7 million metric tonnes of rice are consumed annually. 57% of the 6.7 million metric tonnes are locally produced leading to a deficit of 3 million metric tonnes (KPMG, 2019).

Despite the increase of rice production in Nigeria the gap between production and consumption continue to increase (Garba and Fushion, 2007). This is due to many problems facing the Nigerian agriculture in general and rice production in particular. Recently, many technologies are been made available to meet the demand on rice in Nigeria which is still on the low side due to some production constraints. These ranges from rice seed varieties, water and irrigation, diseases and pest control, crop management, access to technology and soil fertility (KPMG, 2019). Declining soil fertility is one of the major problems militating against increase in rice production. According to Ahmed et al. (2003), modern crop varieties cannot achieve their genetic potential unless good soil fertility is maintained. However, in order to enhance local production meet up with the present demand and consumption of rice in Nigeria, soil fertility issue must be tackled.

Soil fertility decline could be alleviated through fertilizer application, Fertilizer application could only be effective if the type and quality of fertilizer to be applied depends on soil test result, otherwise soil abuse and low yield may be the result. Hence, this work is intended to assess the nutrient status of the two major rice production system (rain-fed lowland and upland) in Okigwe area of Imo State Nigeria. In addition this work also studied the relationship of the nutrient contents with the physical and chemical properties of the soil.


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Volume 7, Issue 2, 2024 (pp. 187-198)


## Materials and Methods

### Description of Study Area

The study area is Okigwe in southeastern Nigeria. Geographically, it is located between latitudes 5.819283 and longitudes 7.340854 (Iwuji et al, 2022). The study area occupies a landmass of about 360 km$^2$ (NBS, 2006). Okigwe has a tropical climate, an average temperature of 28$^o$C and annual rainfall of 1800mm to 2000mm. The duration of rainy season and dry season in the area are May to October and November to April respectively (Ajiere et al, 2021). There is high prevalence of relief variation within the study area. Below are the geographical co-ordinated where soil samples were collected from the study area.

**Table 1: Details of sampling points**

| Farms | GPS coordinates of sampling points | Elevation (meters) |
|---|---|---|
| Lowland 1 | Lat 5.876900; Long 7.224730 | 103.8 |
| Lowland 2 | Lat 5.877133; Long 7.224883 | 105.6 |
| Lowland 3 | Lat 5.877699; Long 7.225037 | 107.0 |
| Lowland 4 | Lat 5.877210; Long 7.224424 | 106.1 |
| Lowland 5 | Lat 5.877307; Long 7.22638 | 106.6 |
| Upland 1 | Lat 5.871353; Long 7.228477 | 101.0 |
| Upland 2 | Lat 5.871489; Long 7.228180 | 103.4 |
| Upland 3 | Lat 5.871581; Long 7.228345 | 106.2 |
| Upland 4 | Lat 5.871486; Long 7.228631 | 105.6 |
| Upland 5 | Lat 5.871379; Long 7.228472 | 104.2 |

### Soil Sampling and Preparation

Ten (10) rice farms was used for the study, 5 were of rain-fed lowland rice production system while 5 were of upland rice production system. In all 30 soil samples made up of fifteen (15) rain-fed lowland and fifteen (15) upland rice farm soils were obtained from the study area. 3 samples each were collected from each rice farm (beginning, middle and end) which was homogenized to form a composite sample. Five composite soil samples were collected from each of the rice production system making a total of 10 composite soil samples for the research. The samples were collected at a depth of 15 cm using an auger. The soil samples were air dried, crushed and sieved using a 2 mm sieve. The sieved samples were packaged and well labeled ahead of Laboratory analysis.

### Laboratory Analysis

Particle size distribution otherwise known as mechanical analysis was determined by hydrometer method (Bouyoucos, 1962) using sodium hexametaphosphate as dispersant. The texture class was also determined using the 'textured triangular diagram' (Loganathan, 1984). Soil pH was measured in water suspension (1:2.5) using the glass electrode coupled pH meter (Thomas, 1996). The cation exchange capacity (CEC) and exchangeable cations were determined by extracting the cations with 1 M ammonium acetate buffered at pH 7(Thomas, 1982). Calcium (Ca) and magnesium (Mg) were determined by EDTA titration while


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potassium (K) and sodium (Na) were determined by flame photometry. Available phosphorous (Av. P) was extracted with Bray solution 11 and the phosphorous determined by the molybdenum method as described by Udo and Ogunwale (1978). The percent organic matter (% OM) was calculated from the percent organic carbon (% OC) measured using Walker-Black wet oxidation method. Total nitrogen (TN) was determined using the modified Kjeldahl distillation methods (Juo, 1979). The available micronutrients (B, Cu, Mn, Zn and Fe) in the soil were extracted using DTPA and determined with atomic absorption spectrophotometer, a method developed by Lindsay and Norvell, 1978.

**Data Analysis**

Descriptive statistics which included mean and standard deviation (SD) were obtained using SPSS (IBM SPSS Statistics version 25). The coefficient of variation (CV) which is a ratio of standard deviation to mean and expressed as a percentage was also calculated for each measured variable. T- Test analysis was done to compare the variations between the soil properties of the rain-fed lowland and upland rice production system. Correlation analysis was performed to assess relationships among the soil parameters and was computed using Microsoft Excel 2010.

## RESULTS AND DISCUSSION

The mean, standard deviation and percentage coefficient of variation of the particle size distribution in the sampled rain-fed lowland and upland rice production soils were shown on Table 2. The Table indicates that the percentage clay in the rain-fed lowland soil had a mean of 16.00%, standard deviation of 1.41 and percentage coefficient of variation of 8.81. Silt recorded a mean of 18.40%, standard deviation of 1.52 and percentage coefficient of variation of 8.23. The mean for percentage sand is 65.60%, standard deviation of 1.82 and percentage coefficient of variation of 2.77.

In the upland rice production soils, clay had a mean of 12.40%, standard deviation of 0.55 and percentage coefficient of variation of 4.42. Silt had a mean of 16.60%, standard deviation of 2.61 and percentage coefficient of variation of 15.71. The mean for percentage sand are 71.00%, standard deviation of 2.92 and percentage coefficient of variation of 4.11. Both the rain-fed lowland and upland rice production soils have a sandy loam texture. Comparing between the rain-fed lowland and upland, soil particle size had % TS and % clay as the soil particle with significant differences (0.008** and 0.01* respectively) (Table 2). The higher % clay is because clay differ even among adjacent fields depending on topography (Moritsuka et al., 2014; Katsura et al., 2018). The higher sand fraction obtained in this study is in agreement with the work of Gupta et al., 2019 in Jhartkland where upland soils have higher sand fraction with lower silt and clay comparative to lowland.


Article DOI: 10.52589/AJAFS-GI5TF3ZK
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**Table 2: Physical Characteristics of soils from Rain-fed lowland and Upland rice production systems**

| Farm | % Clay | % Silt | % Sand | Textural Class |
|---|---|---|---|---|
| | | Rain-fed lowland | | |
| 1 | 16.0 | 20.0 | 64.0 | Sandy loam |
| 2 | 16.0 | 17.0 | 67.0 | Sandy loam |
| 3 | 14.0 | 18.0 | 68.0 | Sandy loam |
| 4 | 18.0 | 17.0 | 65.0 | Sandy loam |
| 5 | 16.0 | 20.0 | 64.0 | Sandy loam |
| Mean ± SD | 16.0 ± 1.41 | 18.40 ± 1.52 | 65.60 ± 1.82 | |
| % CV | 8.81 | 8.23 | 2.77 | |
| | | Upland | | |
| 1 | 12.0 | 13.0 | 75.0 | Sandy loam |
| 2 | 12.0 | 15.0 | 73.0 | Sandy loam |
| 3 | 12.0 | 19.0 | 69.0 | Sandy loam |
| 4 | 13.0 | 17.0 | 70.0 | Sandy loam |
| 5 | 13.0 | 19.0 | 68.0 | Sandy loam |
| Mean ± SD | 12.40 ± 0.55 | 16.60 ± 2.61 | 71.00 ± 2.92 | |
| % CV | 4.42 | 15.71 | 4.11 | |
| t-test | 5.308 | 1.334 | -3.515 | |
| P value | 0.01* | ns | 0.008** | |

****=Significant at P < 0.01, *=Significant at P < 0.05, ns = not significant at both P < 0.01 and P < 0.05**

**Chemical Characteristics of soils from Rain-fed Lowland and Upland rice production systems**

The mean, standard deviation and percentage coefficient of variation of the soil chemical characteristics of both the rain-fed lowland and upland in the study area are shown on Table 3. The Table indicated that the mean for pH is 4.66, standard deviation of 0.27 and percentage coefficient of variation of 20.18. OM had a mean concentration of 3.80%, standard deviation of 0.86 and percentage coefficient of variation of 22.71. The total nitrogen (TN) in the rain-fed lowland soil had a mean of 0.19%, standard deviation of 0.03 and percentage coefficient of variation of 15.47. Available phosphorus recorded a mean of 12.50mg $kg^{-1}$, standard deviation of 2.52 and percentage coefficient of variation of 20.18. The means exchangeable calcium, magnesium and potassium were 0.64Cmol $kg^{-1}$; 0.80Cmol $kg^{-1}$; 0.17Cmol kg-1, standard deviation of 0.14; 0.15; 0.02 and percentage coefficient of variation of 21.77; 18.83; 13.85 respectively. The mean concentration of exchangeable sodium is 0.04Cmol $kg^{-1}$ with a standard deviation of 0.01 and a percentage coefficient of variation of 21.38. CEC had a mean of 33.36Cmol $kg^{-1}$, standard deviation of 4.90 and percentage coefficient of variation of 14.68.

In the upland rice production soils, mean for pH is 6.58, standard deviation of 0.24 and percentage coefficient of variation of 14.25. OM had a mean concentration of 3.16%, standard deviation of 0.56 and percentage coefficient of variation of 17.66. The TN had a mean of 0.23%, standard deviation of 0.02 and percentage coefficient of variation of 9.12. Available phosphorus had a mean of 22.01mg $kg^{-1}$, standard deviation of 3.14 and percentage


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DOI URL: https://doi.org/10.52589/AJAFS-GI5TF3ZK

coefficient of variation of 14.25. Exchangeable potassium had corresponding values of 0.14Cmol kg$^{-1}$, 0.05 and 34.33 for mean, standard deviation and percentage coefficient of variation. The mean for exchangeable calcium and magnesium are 1.16Cmol kg$^{-1}$; 1.00Cmol kg$^{-1}$, standard deviation of 0.23; 0.56 and percentage coefficient of variation of 20.08; 56.01 respectively. The mean concentration of exchangeable sodium is 0.04Cmol kg$^{-1}$ with a standard deviation of 0.01 and a percentage coefficient of variation of 23.54. CEC had a mean of 39.04Cmol kg$^{-1}$, standard deviation of 3.82 and percentage coefficient of variation of 9.79.

Comparative assessment of the soil chemical characteristics between the rain-fed lowland and upland had pH (0.0005**), TN (0.038*), Available P (0.01*) and Exch. Ca (0.03*) as the only soil chemical characteristics with a significant difference (Table 3). The low pH found in rain-fed lowland soils could be attributed to the leaching which occurs frequently in them and thus reducing the cations which could have ordinarily increased the soil pH. Variation was also found in TN with upland soils (0.23%) showing higher value in TN than rain-fed lowland soils (0.19%). The low TN in rain-fed lowland soils might be due to the chemical reactions occurring under reduced conditions. They include denitrification, ammonia volatilization, clay fixation and losses in run-off water (Patrick et al., 1985). Significant difference was observed in available P between rain-fed lowland soils and upland soil used for rice production system (Table 3). High fixation of P and leaching of P in lowland rice farm might be the reason for its low value in the soils of rain-fed lowland rice (Xiao, 1988).

The t-test results obtained from the evaluated exchangeable cations had Ca to be the only exchangeable cation with significant difference with upland showing higher value (1.16Cmol kg$^{-1}$). Although the exchangeable Mg showed no significant effect, higher Mg was also found in the upland soil under rice cultivation. The continuous and intermittent waterlogging of soil in rice lowland or paddies causes immobilization and leaching of Ca and Mg, which substantially limit their availability for crop (IITA, 2022). Exchangeable K represents the fraction of potassium which is adsorbed on external and accessible internal soil surfaces. This depends solely on soil texture, clay mineralogy and K input from natural sources. Dobermann et al., 1996a and Dobermann et al., 1996b also indicated that excessive Ca and Mg compared to K reduces K uptake by rice. Low Na found in both rain-fed lowland and upland is a function of parent material. According to Kawaguchi and Kyuma (1974), Na is one of the most mobile elements in the soil especially where climate is humid; it is leached out regardless of their physiographic position. The low Na value found is also in agreement with that reported by Kyuma 2004 in some Japanese lowland soils.


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**Table 3: Chemical Characteristics of soils from Rain-fed lowland and Upland rice production systems**

| Farm | pH | OM | TN | Av. P | Ex. Ca | Ex. Mg | Ex. K | Ex. Na | CEC |
|---|---|---|---|---|---|---|---|---|---|
| | | % | | mg kg$^{-1}$ | Cmol kg$^{-1}$ | | | | |
| | | | | Rain-fed lowland | | | | | |
| 1 | 5.1 | 4.13 | 0.18 | 14.92 | 0.67 | 0.62 | 0.18 | 0.05 | 36.8 |
| 2 | 4.5 | 3.03 | 0.17 | 13.99 | 0.67 | 0.84 | 0.20 | 0.06 | 40.0 |
| 3 | 4.4 | 5.09 | 0.15 | 12.12 | 0.49 | 0.98 | 0.16 | 0.04 | 28.8 |
| 4 | 4.6 | 3.72 | 0.21 | 13.06 | 0.84 | 0.89 | 0.16 | 0.04 | 32.0 |
| 5 | 4.7 | 3.03 | 0.22 | 8.39 | 0.53 | 0.67 | 0.14 | 0.03 | 29.2 |
| Mean ± SD | 4.66±0.27 | 3.80±0.86 | 0.19±0.03 | 12.50±2.52 | 0.64±0.14 | 0.80±0.15 | 0.17±0.02 | 0.04±0.01 | 33.36±4.90 |
| % CV | 5.80 | 22.71 | 15.47 | 20.18 | 21.77 | 18.83 | 13.85 | 21.38 | 14.68 |
| | | | | | Upland | | | | |
| 1 | 6.3 | 2.68 | 0.23 | 27.05 | 1.20 | 0.31 | 0.22 | 0.04 | 38.0 |
| 2 | 6.6 | 3.37 | 0.24 | 21.45 | 1.02 | 0.80 | 0.11 | 0.05 | 42.0 |
| 3 | 6.4 | 3.78 | 0.20 | 18.65 | 1.42 | 1.69 | 0.10 | 0.02 | 36.0 |
| 4 | 6.7 | 3.51 | 0.22 | 20.52 | 1.33 | 1.47 | 0.14 | 0.04 | 44.0 |
| 5 | 6.9 | 2.48 | 0.25 | 22.38 | 0.84 | 0.76 | 0.13 | 0.04 | 35.2 |
| Mean ± SD | 6.58±0.24 | 3.16±0.56 | 0.23±0.02 | 22.01±3.14 | 1.16±0.23 | 1.00±0.56 | 0.14±0.05 | 0.04±0.01 | 39.0±3.82 |
| % CV | 3.63 | 17.66 | 9.12 | 14.25 | 20.08 | 56.01 | 34.33 | 23.54 | 9.79 |
| t-test | -11.907 | 1.378 | -2.483 | -5.286 | -4.308 | -0.784 | 1.000 | 1.151 | -2.045 |
| P value | 0.0005** | ns | 0.038* | 0.01* | 0.03* | ns | ns | ns | ns |

**=Significant at P < 0.01, * = Significant at P < 0.05, ns = not significant at both P < 0.01 and P < 0.05**

## Micronutrients of soils from Rain-fed lowland and Upland rice production systems

The mean, standard deviation and percentage coefficient of variation of some selected micro nutrient parameters in the sampled rain-fed lowland and upland rice production soils are presented in table 4. In the rain-fed lowland rice production soils, B had a mean of 8.72 mg kg$^{-1}$, standard deviation of 2.37 and percentage coefficient of variation of 27.18. Cu concentrations had a mean of 1.15 mg kg$^{-1}$, standard deviation of 0.80 and percentage coefficient of variation of 69.57. Mn and Zn both had a mean of 3.46; 4.55 mg kg$^{-1}$, standard deviation of 1.30; 1.34 and percentage coefficient of variation of 37.57; 29.45 respectively while Fe had a mean of 1.55 mg kg$^{-1}$, standard deviation of 0.53 and percentage coefficient of variation of 34.19.

The Table 4 also indicates that B under upland production system had a mean of 6.05 mg kg$^{-1}$, standard deviation of 1.63 and percentage coefficient of variation of 26.94. Cu concentrations had a mean of 2.39 mg kg$^{-1}$, standard deviation of 0.92 and percentage coefficient of variation of 38.49. Mn and Zn both had a mean of 3.20; 7.05 mg kg$^{-1}$, standard deviation of 1.23; 2.17 and percentage coefficient of variation of 38.44; 30.78 respectively. Lastly, Fe had a mean of 1.90 mg kg$^{-1}$, standard deviation of 0.27 and percentage coefficient of variation of 13.92.

The results of the t-test between the rain-fed lowland and upland soils under rice production on selected micronutrients showed significant effect only with B (0.02*). According to Nayyar et al. (2001), boron deficiency often occurs in the soil with low organic matter and coarse texture that is prone to leaching. In this study soils of the rain-fed lowland had lower % sand than upland soils. Despite not been significant, a clear variation was seen in Zn concentration among the two studied soils (rain-fed lowland and upland). According to Rose et al. (2013), rain-fed lowland rice is most affected by Zn deficiency because of low soil


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African Journal of Agriculture and Food Science
ISSN: 2689-5331
Volume 7, Issue 2, 2024 (pp. 187-198)


redox potential resulting from the intermittent flooding. Again, interaction and antagonisms such as Zn-N, Zn-Fe, Zn-P and Zn-Cu were considered the main soil factors associated with Zn deficiency in submerged paddy soils (Patrick et al., 1985).

**Table 4: Some selected micronutrients of soils from Rainfed lowland and Upland rice production systems**

| Farm | B | Cu | Mn | Zn | Fe |
|---|---|---|---|---|---|
| | | | mg kg$^{-1}$ | | |
| | | | Rainfed lowland | | |
| 1 | 9.51 | 2.06 | 2.68 | 4.94 | 2.16 |
| 2 | 7.35 | 1.36 | 2.32 | 4.65 | 1.77 |
| 3 | 11.46 | 1.60 | 3.54 | 4.35 | 1.70 |
| 4 | 10.38 | 0.55 | 4.88 | 6.10 | 1.15 |
| 5 | 7.35 | 0.85 | 3.17 | 3.77 | 1.36 |
| Mean ± SD | 8.72±2.37 | 1.15±0.80 | 3.46±1.30 | 4.55±1.34 | 1.55±0.53 |
| % CV | 27.18 | 69.57 | 37.57 | 29.45 | 34.19 |
| | | | Upland | | |
| 1 | 3.46 | 3.13 | 2.44 | 4.94 | 2.02 |
| 2 | 6.27 | 1.69 | 1.95 | 6.24 | 2.23 |
| 3 | 6.27 | 3.61 | 4.39 | 9.73 | 1.95 |
| 4 | 6.27 | 1.94 | 4.64 | 9.00 | 2.02 |
| 5 | 8.00 | 1.56 | 2.56 | 5.37 | 1.50 |
| Mean ± SD | 6.05±1.63 | 2.39±0.92 | 3.20±1.23 | 7.05±2.17 | 1.94±0.27 |
| % CV | 26.94 | 38.49 | 38.44 | 30.78 | 13.92 |
| t-test | 2.877 | -2.244 | 0.173 | -2.193 | -1.474 |
| P value | 0.02* | ns | ns | ns | ns |

*** = Significant at P < 0.05, ns = not significant at both P < 0.01 and P < 0.05**

### Inter-element relationships in rain-fed lowland and upland rice production soils in Okigwe

The inter-element relationship in the rain-fed lowland rice production soils in Okigwe was presented on Table 5a. It was found that OM had a strong positive association with B (0.91) but however, had a negative association with % Clay (-0.56) and TN (-0.60). TN correlated negatively and strongly with % TS (-0.81) and Cu (-0.70) and a weak negative association with Na (-0.57), K (-0.55), Mg (-0.50), available P (-0.57) and Fe (-0.64). Na had a very strong positive correlation with K (0.98), CEC (0.93) and Available P (0.77) with its association with Fe (0.53) positively weak while maintaining a negative association with Mn (-0.54). K had a positively strong relationship with CEC (0.94) and Available P (0.89) and a weak one with Fe (0.56). Ca correlated positively and strongly with % clay (0.90) and Zn (0.92) with a weak positive correlation on available P (0.51). Mg correlated negatively with pH (-0.87) and % silt (-0.83). Mg however also had a positive and strong correlation with % TS (0.85) and a weak correlation with B (0.56). CEC associated positively and strongly with Available P (0.73) but weakly with Fe (0.55) and a weak negative association with Mn (-0.59). Available P associate positively with three out of the five selected micronutrients evaluated. The associations were 0.54, 0.60 and 0.59 in Cu, Zn and Fe respectively. pH had a strong association in both direction with % silt (0.72) and % TS (-0.80). % Clay had a weak


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DOI URL: https://doi.org/10.52589/AJAFS-GI5TF3ZK

negative correlation with % TS (-0.58), Cu (-0.62) and Fe (-0.50) and a strong positive association with Zn (0.72). % Silt had a weak negative association with % TS (-0.65) and Zn (-0.54). Cu had a strong positive association with Fe (0.98) and a weak negative association with Mn (-0.66). B had a weak correlation with Mn (0.59). Lastly, Mn correlated negatively and strongly with Fe (-0.76) but positively weak with Zn (0.63). Generally, TN had a negative correlation with more nutrients than any other nutrients' studied on lowland rice production soil. This implies that TN concentration is the major determinant of the other nutrients' concentration in the rain-fed lowland rice production soil. This major determinant correlated negatively with OM, an implication that an increase in TN implies a decrease in OM and also a decrease in nutrient availability.

**Table 5a. Inter-nutrient relationship of soils from Rain-fed lowland rice production system**

| | *OM* | *TN* | *Na* | *K* | *Ca* | *Mg* | *CEC* | *Av. P* | *pH* | *%clay* | *%silt* | *%TS* | *Cu* | *B* | *Mn* | *Zn* | *Fe* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OM | 1 | | | | | | | | | | | | | | | | |
| TN | **-0.60** | 1 | | | | | | | | | | | | | | | |
| Na | -0.19 | **-0.57** | 1 | | | | | | | | | | | | | | |
| K | -0.10 | **-0.55** | **0.98** | 1 | | | | | | | | | | | | | |
| Ca | -0.30 | 0.32 | 0.31 | 0.43 | 1 | | | | | | | | | | | | |
| Mg | 0.45 | **-0.50** | 0.10 | 0.07 | 0.02 | 1 | | | | | | | | | | | |
| CEC | -0.39 | -0.31 | **0.93** | **0.94** | 0.41 | -0.23 | 1 | | | | | | | | | | |
| Av. P | 0.26 | **-0.57** | **0.77** | **0.89** | **0.51** | 0.11 | **0.73** | 1 | | | | | | | | | |
| pH | -0.10 | 0.30 | -0.01 | 0.12 | 0.20 | **-0.87** | 0.29 | 0.27 | 1 | | | | | | | | |
| %clay | **-0.56** | **0.68** | 0.04 | 0.12 | **0.90** | -0.21 | 0.23 | 0.13 | 0.26 | 1 | | | | | | | |
| %silt | -0.01 | 0.33 | -0.47 | -0.44 | -0.46 | **-0.83** | -0.23 | -0.35 | **0.72** | -0.23 | 1 | | | | | | |
| %TS | 0.44 | **-0.81** | 0.36 | 0.27 | -0.32 | **0.85** | 0.01 | 0.19 | **-0.80** | **-0.58** | **-0.65** | 1 | | | | | |
| Cu | 0.49 | **-0.70** | 0.40 | 0.44 | -0.39 | -0.23 | 0.38 | **0.54** | 0.42 | **-0.62** | 0.37 | 0.18 | 1 | | | | |
| B | **0.91** | -0.39 | -0.25 | -0.12 | 0.05 | **0.56** | -0.43 | 0.29 | -0.15 | -0.21 | -0.22 | 0.34 | 0.18 | 1 | | | |
| Mn | 0.24 | 0.40 | **-0.54** | -0.44 | 0.47 | 0.44 | **-0.59** | -0.16 | -0.26 | 0.48 | -0.35 | -0.08 | **-0.66** | **0.59** | 1 | | |
| Zn | 0.09 | 0.09 | 0.23 | 0.38 | **0.92** | 0.27 | 0.24 | **0.60** | 0.09 | **0.72** | **-0.54** | -0.10 | -0.27 | 0.44 | **0.63** | 1 | |
| Fe | 0.30 | **-0.64** | **0.53** | **0.56** | -0.29 | -0.34 | **0.55** | **0.59** | 0.49 | **-0.50** | 0.36 | 0.09 | **0.98** | 0.00 | **-0.76** | -0.25 | 1 |

Table 5b presented the inter-element relationship in the upland rice production soils in Okigwe. It was found that OM had a strong negative association with TN (-0.75) and Avail P (-0.77) but however, had a strong positive association with Ca (0.75), Mg (0.83) and Zn (0.89). OM also has weak positive association with Mn (0.65) and Fe (0.60) and a weak negative on K (-0.58). TN had a lot of negative association with many elements though some are weakly correlated while some are of strong association. They include Ca (-0.93), Mg (-0.65), Cu (-0.86), Mn (-0.69) and Zn (-0.76). Their positive associations were with Na (0.83) and pH (0.69). Na had a negatively strong correlation with Ca (-0.75), Mg (-0.72), Cu (-0.73), Mn (-0.83) and Zn (-0.75) and a weak negative association with % Silt (-0.54). K had a positively strong relationship with available P (0.91) and a weak positive correlation on % TS (0.64), but negatively correlated with Mg (-0.66), % silt (-0.70), B (-0.78) and Zn (-0.54). Ca had a weak negative correlation with pH (-0.63) and a positive association with Mg (0.64), Cu (0.73), Mn (0.79) and Zn (0.78). Mg correlated negatively with Avail P (-0.91) and % TS (-0.65) and positively with % Silt (0.69), Mn (0.88) and Zn (0.98) while Avail P had a negative association with % silt (-0.76), B (-0.66), Mn (-0.62) and Zn (-0.83) and a positive association on % TS (0.71). CEC had a weak positive correlation with only Fe (0.69). pH showed a strong positive correlation with % Clay (0.84) and B (0.86) and a weak correlation with % Silt (0.55). pH also had a negative association with Cu (-0.86) and Fe (-0.58). % Clay associated negatively and weakly with % TS (-0.63), Cu (-0.63) and Fe (-0.62) but positively


Article DOI: 10.52589/AJAFS-GI5TF3ZK
DOI URL: https://doi.org/10.52589/AJAFS-GI5TF3ZK

with B (0.60). % Silt positively correlated and strongly with B (0.84) and weakly with Mn (0.52) and Zn (0.53) but showed a negative association with % TS (-0.99) and Fe (-0.62). % TS correlated negatively with B (-0.86) and Mn (-0.52) and positively with Fe (0.67). Cu had a negative association with B (-0.58) with B correlating negatively also with Fe (-0.56). Finally, a strong and positive relationship was observed between Zn and Mn (0.91). Generally, TN also had a negative correlation with more nutrients than any other nutrients studied on upland rice production soil as also seen in lowland soil. An implication too that TN concentration is the major determinant of the other nutrients' concentration in the upland rice production soil. Though compared to the findings on the rain-fed lowland soils, OM in upland soils had more positive association with other nutrients. This explains the reason why more nutrients were found to be available in upland soils relative to the lowland soils.

**Table 5b. Inter-nutrient relationship of soils from Upland rice production system**

| | *OM* | *TN* | *Na* | *K* | *Ca* | *Mg* | *CEC* | *Av. P* | *pH* | *%clay* | *%silt* | *%TS* | *Cu* | *B* | *Mn* | *Zn* | *Fe* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OM | 1 | | | | | | | | | | | | | | | | |
| TN | **-0.75** | 1 | | | | | | | | | | | | | | | |
| Na | -0.48 | **0.83** | 1 | | | | | | | | | | | | | | |
| K | **-0.58** | 0.12 | 0.15 | 1 | | | | | | | | | | | | | |
| Ca | **0.75** | **-0.93** | **-0.75** | 0.03 | 1 | | | | | | | | | | | | |
| Mg | **0.83** | **-0.65** | **-0.72** | **-0.66** | **0.64** | 1 | | | | | | | | | | | |
| CEC | 0.42 | 0.05 | 0.36 | -0.03 | 0.23 | 0.15 | 1 | | | | | | | | | | |
| Av. P | **-0.77** | 0.41 | 0.47 | **0.91** | -0.33 | **-0.91** | -0.11 | 1 | | | | | | | | | |
| pH | -0.28 | **0.69** | 0.33 | -0.43 | **-0.63** | 0.08 | 0.07 | -0.29 | 1 | | | | | | | | |
| %clay | -0.28 | 0.48 | 0.03 | -0.08 | -0.29 | 0.17 | 0.13 | -0.16 | **0.84** | 1 | | | | | | | |
| %silt | 0.24 | -0.14 | **-0.54** | **-0.70** | 0.01 | **0.69** | -0.39 | **-0.76** | **0.55** | 0.49 | 1 | | | | | | |
| %TS | -0.16 | 0.03 | 0.48 | **0.64** | 0.05 | **-0.65** | 0.32 | **0.71** | **-0.65** | **-0.63** | **-0.99** | 1 | | | | | |
| Cu | 0.33 | **-0.86** | **-0.73** | 0.25 | **0.73** | 0.22 | -0.39 | 0.03 | **-0.86** | **-0.63** | -0.08 | 0.19 | 1 | | | | |
| B | 0.04 | 0.34 | 0.00 | **-0.78** | -0.43 | 0.41 | -0.15 | **-0.66** | **0.86** | **0.60** | **0.84** | **-0.86** | **-0.58** | 1 | | | |
| Mn | **0.65** | **-0.69** | **-0.83** | -0.23 | **0.79** | **0.88** | 0.16 | **-0.62** | -0.05 | 0.30 | **0.52** | **-0.52** | 0.36 | 0.13 | 1 | | |
| Zn | **0.89** | **-0.76** | **-0.75** | **-0.54** | **0.78** | **0.98** | 0.23 | **-0.83** | -0.10 | 0.05 | **0.53** | -0.49 | 0.35 | 0.21 | **0.91** | 1 | |
| Fe | **0.60** | -0.38 | 0.18 | 0.02 | 0.47 | 0.07 | **0.69** | -0.02 | **-0.58** | **-0.62** | **-0.62** | **0.67** | 0.20 | **-0.56** | -0.01 | 0.22 | 1 |

## CONCLUSION

The CEC, pH, Ca, P, Mg and TN were lower in rain-fed lowland rice soils but higher in upland soils. Though not significant, OM was found to be slightly higher in rain-fed lowland rice production. This implies that the concentration of available nutrients in the soil could largely depend on pH. pH being critical in the determination of chemical, physical and biological soil qualities and a pH range of 6.5 to 7.5 is ideal for nutrient availability for plants. The acidic pH range of 4.4 to 5.1 observed in the lowland soils negatively influenced the availability of nutrients in lowland rice production soil. However, the pH ranges of 6.3 to 6.9 observed in upland soils, favoured conditions for more availability of nutrients.

The result of correlation showed TN as the major determinant of the other nutrients in the soil. TN was found to be slightly lower in the lowland rice production soils compared to the upland soils. However, despite TN being the perceived major determinant because of many negative correlations it has with other nutrients including OM. OM in upland soils had more positive association with other nutrients compared to that in the lowland soils. This in turn, might be the reason for the lower availability of nutrients in lowland soils compared to the upland soils. This study thus recommends use of organic material as a strategy of improving


Article DOI: 10.52589/AJAFS-GI5TF3ZK
DOI URL: https://doi.org/10.52589/AJAFS-GI5TF3ZK

pH, OM and the nitrogen content in the lowland rice production soils. This will enhance the availability of nutrients in the lowland soils and equally improve rice growth and yield.

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DOI URL: https://doi.org/10.52589/AJAFS-GI5TF3ZK