

## Development of Compositional Nutrient Diagnosis (CND) Norms and Indices of Rice (*Oryza sativa*) in Dutsin-Ma, Katsina State Nigeria

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### Abstract

A field experiment was conducted during the 2023 dry season to determine the Compositional Nutrient Diagnosis (CND) norms, indices, and nutrient uptake by three rice varieties (Jasmine, Giza, and Faro 44). The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Leaf samples were analyzed for major (N, P, and K), secondary (Ca, Mg, and S), and micronutrients (Zn, Cu, Fe, Mn, and B). Results showed significant differences in nutrient uptake among the varieties. Jasmine had the highest N concentration (2.233%), while Faro 44 had the highest P (0.4167%) and K (2.967%) concentrations. The CND norms indicated higher K requirement compared to N. The CND indices identified N, Zn, Cu, and Mn as the most common yield-limiting nutrients in rice. The study demonstrates the effectiveness of CND norms and indices in diagnosing nutrient imbalances and optimizing fertilizer application for rice production in Dutsin-Ma, Katsina State, Nigeria. The findings provide valuable information for farmers and agricultural practitioners to improve rice productivity and reduce yield gaps in the region. This research is the first of its kind in the study area, and its results will contribute to the development of sustainable rice production practices in Nigeria.

**Keywords:** Nutrient Uptake, CND, Norms, Indices, Rice.

### Introduction

Rice is the primary food consumed by the world's population, more than any other crop (Ahmad et al. 2019; Ahmad and Hasanuzzaman 2012; Shahzad and Ahmad 2019). The main rice producers and consumers are in Asia, accounting for more than 90% of global production (Ahmed and Fayyaz-ul-Hassan 2017; Ahmed et al. 2020; Akram et al. 2018, 2019; Hussain et al. 2018; Fahad et al. 2019; Fatima et al. 2020). It is a staple food for the majority of the population in this continent, distinguishing it from the rest of the world (FAO 2008; Hafeez-ur-Rehman et al. 2019; Khan et al. 2019a, b; Naz et al. 2019; Peerzada et al.

2019; Razaq et al. 2019; Sarwar et al. 2013; Tariq et al. 2020; Wasaya et al. 2019; Zahoor et al. 2019).

In most rice-producing regions, rice is deeply rooted in culture and traditions, and is notable for its diverse and exciting farming systems. Rice production increased more than threefold after the introduction of high-yielding varieties during the Green Revolution of the late 1960s. This was made possible by the introduction of improved rice cultivars, irrigation facilities, and subsidized inputs.

Globally, rice is produced on approximately 158 million hectares, with an annual production of over 700 million tons (470 million tons of milled rice). The top ten rice-producing countries are China, India, Indonesia, Bangladesh, Vietnam, Thailand, Myanmar, the Philippines, Japan, and Brazil. Asia accounts for almost 90% of global rice production (640 million tons), while Latin America and Sub-Saharan Africa produce 25 million tons and 19 million tons, respectively (Atique-ur-Rehman et al. 2014, 2018).

Rice can be cultivated in various environments and is productive in situations unsuitable for other crops. It is grown on a wide range of soils, with average yields ranging from less than 1 ton per hectare in poor rainfed environments to over 10 tons per hectare in intensive temperate irrigated systems. (Mahmud et al 2022).

Rice is a staple food crop in Nigeria, playing a crucial role in food security and economic development. Katsina State, located in the northern part of the country, is one of the major rice-producing regions. However, rice productivity in the state is often limited by suboptimal nutrient management practices, leading to yield gaps and reduced profitability for farmers. Compositional Nutrient Diagnosis (CND) is a powerful tool for evaluating crop nutrient status and identifying nutrient limitations. Despite its potential, CND norms and indices have not been established for rice production in Dutsin-Ma, Katsina State, Nigeria, making it challenging for farmers and agricultural practitioners to optimize nutrient management.

The Compositional Nutrient Diagnosis (CND) method considers the relationship between a given nutrient and the geometric mean of concentrations, on a dry matter basis, recorded for other nutrients (multivariable relations), including those not analytically determined. This technique was developed in Canada and has been applied worldwide to various annual crops, including rice (Parent and Dafir, 1992; Khiari et al., 2001).

Rice production in Dutsin-Ma, Katsina State, Nigeria, is constrained by inadequate nutrient management, resulting in low yields and reduced economic returns. The lack of established Compositional Nutrient Diagnosis (CND) norms and indices for rice varieties in the study area hinders the development of effective nutrient management strategies. As this research is the first of its kind in the study area, there is a pressing need to determine CND norms and indices for rice production, which will serve as a foundation for optimizing nutrient management practices, improving rice productivity, and enhancing food security in the region.

Additionally, soil analysis has been challenging due to insecurity in the area and the high cost of laboratory analysis, leading to a lack of interest among farmers in conducting soil tests.

The research aimed to assess the level of nutrient uptake by three rice varieties (Jasmine, Giza, and Faro 44) and develop multivariate diagnostic norms and indices for rice in Dutsin-Ma Local Government Area of Katsina State, Nigeria.

## Materials and Methods

### Experimental Site

The experiment was conducted during the 2023 dry season at Songhai Farm Initiative Katsina State, Dutsin-Ma located in Makera village Dutsin-Ma (Latitude N12°20.823 Longitude E007°30.455) in the Sudan Savannah Nigeria. The relative humidity of the study area is moderately high all year-round and the temperature range is between 21°C – 35°C.

### Treatments and Experimental Design

The treatments comprised of three varieties of rice: two exotics (Jasmine and Giza) and one indigenous (Faro44) grown under irrigation ensuring minimal water stress. The experiment was laid in a Randomized Complete Block Design (RCBD) with three replications. The experimental plot consisted of 2m x 2m as gross plot and while the net plot was 1m x 2m (2m<sup>2</sup>).

### Soil Sampling

Soil was sampled from 5 different spots of the field at a depth of 0-30cm using auger and mixed to come up with a composite sample. The sample was air dried, sieved using 2mm sieve and stored in clean and air tight container prior to analysis.

### Soil Analysis

Particle size analysis was conducted using hydrometer method (Bouyoucos, 1951) and pH with a pH meter in 1:2.5 (soil: water) ratio, Nitrogen was determined by micro-kjedahl method of Jackson (1962). Exchangeable cations were determined by extraction with neutral NH<sub>4</sub>AC. potassium, Ca and Na in the extracts will be determined using a flame photometer while Mg was determined with an atomic absorption spectrophotometer. Exchangeable acidity was determined by extracting 2.5ml portion of soil with 25mls of INKCL and 10mls of extracts titrated with 0.01 NaOH using phenolphthalein as indicator. Organic matter was determined by wet dichromate oxidation method (Walkely and Black, 1934). Effective cation exchangeable capacity (ECEC) of each soil sample was taken as sum of the exchangeable bases (Ca, Mg, K, Na) and exchangeable acidity.

## **Tissue Sampling**

The leaf samples of rice were collected from different plots of the cultivated rice farm to establish nutrient concentration for developing diagnostic norms. A total of 90 leaf samples were collected, by selecting the 3rd to 6th leaf from growing tip before bloom stage, which provides the index leaf in rice. About 10 samples were collected from each plot from different plots of rice farm.

## **Cultural Practices**

### **Site selection**

A site of a lowland area with irrigation schemes where water is available for the growth and development was selected for the planting and experiment.

### **Land preparation**

The soil was ploughed, harrowed, and sunken seedbeds measuring 2m × 2m (4m<sup>2</sup>) were made. ed, the field was be sprayed with glyphosate at the rate of 4 L/ha (about 2½ Peak milk tins of chemical/15-L sprayer) to kill emerged weeds. 10 days after glyphosate was sprayed and slashing or mowing of the dead weeds were done.

### **Sowing**

The seeds were sown by drilling in rows at a spacing of 20 cm at rate of 2–3 seedlings per hill, to a depth of 3–4 cm, and at a spacing of 30 × 30cm.

### **Weed control**

Weed control was done manually which was carried out twice, at 2–3 weeks and 5–6 weeks after sowing. Where the weeds were pulled out by hand and with a small hand hoe; and was heaped outside of the field. Before total ground cover was attained to ensure an adequate weed control.

### **Pest and diseases control**

Pest (birds) was controlled through cultural method by beating of metal (pan) to chase away the birds eating the seeds.

## **Tissue Sampling and Analysis**

The leaf samples of rice were collected from different portion of the replicated plots to establish nutrient concentration versus yield data bank for developing diagnostic norms. A total of 90 leaf samples were collected by selecting the 3rd to 6th leaf from growing tip were collected just before bloom stage, which provides the index leaf in rice. About 10 samples were collected from each plot. The leaf samples were decontaminated by washing in a sequentially with tap water, 0.2 per cent detergent solution, 0.1 NHCl and finally with double distilled water. Leaf samples were air dried in a room for 2 weeks.

The samples were then powdered in a cyclotec mill and analysed for different nutrients by digesting 1g tissue in diacid mixture (9:4 ratio of nitric acid and perchloric acid) using standard analytical methods (Jackson, 1973). The samples were analysed for major (N, P and K), secondary (Ca, Mg and S) and micronutrients (Zn, Cu, Fe, Mn and B) by standard method (Piper, 1966; Jackson, 1973 and Jones and Case, 1990). Thus, nutrient concentration vs yield data bank (based on standard procedure, below 30t/ha and above 30t/ha are considered as low yield and high yield) was established for developing nutrient diagnostic norms.

### Calculation of CND Norms and Indices

The CND norms (mean and standard deviation (SD) of the analysed leaf samples) were developed by adopting the procedure outlined by Parent and Dafir (1992). This was accomplished by following the steps proposed by Khiari *et al.* (2001) as follows.

**1<sup>st</sup> step:** To convert all the plant nutrient concentrations to percentage (%).

**2<sup>nd</sup> step:** Sum all the plant nutrient concentration i.e.

$$\text{Total} = (N + P + K + Ca + Mg + Zn + Cu + Fe + Mn + B)$$

**3<sup>rd</sup> step:** Calculate residue ( $R_d$ )

$$R_d = 100 - (N + P + K + Ca + Mg + Zn + Cu + Fe + Mn + B)$$

Where,

$R_d$  = it is the filling value between 100 and the sum of the nutrient proportions.

**4<sup>th</sup> step:** Calculate Geometric mean (G)

$$G = (N * P * K * Ca * Mg * Zn * Cu * Fe * Mn * B)^{1/n}$$

Where,

n = no. of nutrient elements taken for calculation.

**5<sup>th</sup> step:** row centred log ratios of the nutrient proportions ( $Vx$ ) were calculated using the equation.

$$\begin{aligned} VN &= \ln(N/G), VP = \ln(P/G), VK = \ln(K/G), \\ VCa &= \ln(Ca/G), VMg = \ln(Mg/G), \\ VZn &= \ln(Zn/G), VCu = \ln(Cu/G), VFe = \ln(Fe/G), \\ VMn &= \ln(Mn/G) \text{ and } VB = \ln(B/G) \end{aligned}$$

**6<sup>th</sup> step:** CND norms are computed using means and SD corresponding to the row centered log ratios.

$Vx$  of the nutrients for high yielding populations.

$$\begin{aligned} &V * N, V * P, V * K, \dots V * B \text{ i.e.} \\ \text{mean} &= \text{average} (VX1 + VX2 + VX3 + \dots + VXn) \end{aligned}$$

Where,

$Vx$  = average of no. of row centered log ratios of all the nutrients proportions.

$$\begin{aligned} &SD * N, SD * P, SD * K, \dots SD * B \text{ i.e.} \\ SD &= \text{stdev} (VX1 + VX2 + VX3 + \dots + VXn) \end{aligned}$$

Where,

$$Vx = SD \text{ of no. of row centred log ratios of all the nutrients proportions.}$$

**7th step:** the standardized variables  $(VN - V * N)/SD * N$  to  $(VB - V * B)/SD * B$  are *CND* nutrient indices for low yielding population.

$$IN = \frac{(VN - V * N)}{SD * N}, IP = \frac{VP - V * P}{SD * P}, \dots \dots \dots$$

$$IB = (VB - V * B)/SD * B$$

## Data Analysis

All recorded data were subjected to analysis of variance (ANOVA) using GENSTAT version 17 and mean differences were separated using Duncan multiple range test (DMRT) as described by Gomez and Gomez (1984).

## Results and Discussion

### The Characteristics of the Experimental Soil

The experimental soil data presented in table 1 show a range of physical and chemical characteristics of the soil in the study area. The soil texture is predominantly sandy, with sand content ranging between 55% and 63% (mean 58.5%), silt between 21% and 30% (mean 26.5%), and clay between 14% and 16% (mean 15%). This indicates a sandy loam texture, which is common in tropical soils which is in agreement with findings of Adesoji et al.; (2025) and Abdulkadir et al.; (2022). Such soils are well-drained and aerated but may have low water and nutrient retention capacity. The relatively low variance in clay content (0.67) suggests uniformity across the sampled plots (Kahsay et al.; 2025; Sani et al.; 2022). The soil pH ranges from 5.60 to 5.93, with a mean of 5.77, indicating a slightly acidic condition which is in agreement with findings of Mamman et al.; (2025). This acidity level is typical of many cultivated tropical soils and can affect nutrient availability, especially phosphorus and base cations (Sposito, 2016). However, the pH remains within the acceptable range for most arable crops. The electrical conductivity (EC) values (0.01–0.03 dS/m; mean 0.02 dS/m) are very low, confirming that the soil is non-saline and suitable for plant growth (Dawaki et al.; 2019).

The organic carbon (O.C) content (0.34–1.03%, mean 0.57%) is relatively low, indicating poor organic matter status and limited biological activity (Abdulkadir et al.; 2020; Noma and Sani, 2008; Sani et al.; 2019). The total nitrogen (N) content is also low (0.04–0.06%, mean 0.05%), which reflects limited soil fertility. The available phosphorus (P) values range widely (0.89–6.65 mg/kg; mean 3.24 mg/kg), suggesting localized differences in soil P dynamics possibly due to prior fertilizer use or organic matter distribution (Adesoji et al.; 2025).

Exchangeable base cations show moderate variations: calcium (Ca) ranges from 1.76 to 2.67 cmol/kg (mean 2.14), magnesium (Mg) from 0.53 to 0.83 cmol/kg (mean 0.70), potassium (K) from 0.22 to 0.33 cmol/kg (mean 0.27), and sodium (Na) from 0.07 to 0.12 cmol/kg (mean 0.10). These values indicate generally low to moderate nutrient reserves, with Ca dominating the exchange complex, typical of soils derived from base-poor parent materials (Dawaki et al.; 2019). Exchangeable acidity (EA) is low (mean 0.03 cmol/kg), implying

minimal presence of toxic aluminum or hydrogen ions. The effective cation exchange capacity (ECEC) ranges from 2.94 to 3.57 cmol/kg, with a mean of 3.24 cmol/kg, confirming that the soil has low nutrient-holding capacity (Abdulkadir et al.; 2025).

**Table 1: Characteristics of the experimental soil**

|                | Minimum | Maximum | Mean  | Std. Deviation | Variance |
|----------------|---------|---------|-------|----------------|----------|
| Sand (%)       | 55.00   | 63.00   | 58.50 | 3.32           | 11.00    |
| Silt (%)       | 21.00   | 30.00   | 26.50 | 3.87           | 15.00    |
| Clay (%)       | 14.00   | 16.00   | 15.00 | 0.82           | 0.67     |
| pH             | 5.60    | 5.93    | 5.77  | 0.13           | 0.02     |
| EC(dS/m)       | 0.01    | 0.03    | 0.02  | 0.01           | 0.00     |
| O.C (%)        | 0.34    | 1.03    | 0.57  | 0.32           | 0.10     |
| N (%)          | 0.04    | 0.06    | 0.05  | 0.01           | 0.00     |
| P (mg/kg)      | 0.89    | 6.65    | 3.24  | 2.47           | 6.09     |
| Ca (cmol/kg)   | 1.76    | 2.67    | 2.14  | 0.40           | 0.16     |
| Mg (cmol/kg)   | 0.53    | 0.83    | 0.70  | 0.12           | 0.02     |
| K (cmol/kg)    | 0.22    | 0.33    | 0.27  | 0.05           | 0.002    |
| Na (cmol/kg)   | 0.07    | 0.12    | 0.10  | 0.02           | 0.001    |
| EA (cmol/kg)   | 0.00    | 0.05    | 0.03  | 0.02           | 0.000    |
| ECEC (cmol/kg) | 2.94    | 3.57    | 3.24  | 0.30           | 0.087    |

### Nutrient Concentration Range

The mean concentrations of N, P, K, Ca, Mg, Zn, Cu, Fe, Mn and B in leaf of rice are presented in Table 2 and 3. The standard error of difference N concentration was 0.1466% and recorded in the three varieties (JASMIN, GIZA AND FARO44) as 2.233a, 2.033ab, 1.800b. The SED P concentration was 0.02244 % and varied in the varieties as 0.3333b, 0.3400b, 0.4167a. The K concentration varied widely in the varieties as 2.633b, 2.667b, 2.967a % with an SED of 0.0943 %. The increased content of primary nutrients (N, P and K) might be attributed to the better crop growth because of increased availability of nutrients due to application of fertilizers. Besides, application of nutrients in proper balance generally results in better utilization of added nutrients (Vijaykumar, 2010).

Similarly, Ca concentration showed a wide variation ranging as %. The SED Ca (0.022 %) was twice higher to Mg (0.012%), which was comparable to the values reported by Anjaneyulu *et al*, (2008) in guava and Anjaneyulu and Raghupathi (2010) in papaya. The SED leaf concentration of Fe, Cu, Mn, B and Zn were 1.246, 1.858, 1.532, 2.428 and 0.449 ppm, respectively. The optimum recorded conc varied from (29.53ab-27.15b-32.43a), (36.98ab-33.56b-39.48a), (35.18a-28.11b-29.16b), (24.69a-23.43a-26.79a) and (13.16a-10.21b-10.43b) ppm for Fe, Cu, Mn, B and Zn respectively. This was attributed to increased availability of these nutrients due to the supply of these nutrients through micronutrient fertilizers (Vijaykumar, 2010). Gopalakrishnan (2007) reported that the micronutrients for early flower

set and helps in production of growth hormones for their good growth and development for the crops.

**Table2: Varietal difference in nutrient uptake of macronutrients (%)**

| VARIETY                                                   | N       | P       | K      | Ca     | Mg      |
|-----------------------------------------------------------|---------|---------|--------|--------|---------|
| JASMINE                                                   | 2.233a  | 0.3333b | 2.633b | 0.4067 | 0.2167a |
| GIZA                                                      | 2.033ab | 0.3400b | 2.667b | 0.4100 | 0.2400a |
| FARO44                                                    | 1.800b  | 0.4167a | 2.967a | 0.4233 | 0.2167a |
| SED                                                       | 0.1466  | 0.02244 | 0.0943 | 0.022  | 0.01217 |
| Mean were separated using DMRT at 5% level of probability |         |         |        |        |         |

**Table 3: Varietal difference in nutrient uptake of micronutrients (mg/kg)**

| VARIETY                                                   | Fe      | Cu      | Mn     | B      | Zn     |
|-----------------------------------------------------------|---------|---------|--------|--------|--------|
| JASMINE                                                   | 29.53ab | 36.98ab | 35.18a | 24.69a | 13.16a |
| GIZA                                                      | 27.15b  | 33.56b  | 28.11b | 23.43a | 10.21b |
| FARO44                                                    | 32.43a  | 39.48a  | 29.16b | 26.79a | 10.43b |
| SED                                                       | 1.246   | 1.858   | 1.532  | 2.428  | 0.449  |
| Mean were separated using DMRT at 5% level of probability |         |         |        |        |        |

### Compositional Nutrient Diagnosis (CND) Norms

The CND norms are presented in table 4. The CND norms for N (VN), P (VP) and K (VK) for the three varieties of rice (*Oryza sativa*) were N (3.630791, 3.88394, 3.951764), P (2.219179, 2.220435, 2.084497) and K (4.225498, 4.235338, 4.192926). The norms derived indicated higher requirement of K compared to N that might be due to continuous flowering in rice similarly, high CND norm for K was reported in banana (Raghupathiet *al.*, 2002) indicating higher K requirement. The norm for Ca (Vca = 2.269189, 2.325795, 2.271708) was higher compared to that of Mg (VMg = 1.64666, 1.727958, 1.69363) norm. The higher norm value noticed for Ca was mainly due to the presence of high free calcium carbonate in soils, which might have overwhelming influence on calcium uptake. This finding corroborates with the results observed by Anjaneyulu and Raghupathi (2010). Among the micronutrients, Cu requirement was much higher compared to Mn, Zn. Fe and B with a norm value of VCu = -2.32555, -2.44987, -2.5331. CND norms are multivariate norms with due weightage to all the other elements, including the unmeasured factor. Sum of the tissue components is 100 % and therefore the sum of row centred log ratios (including filling value) is zero. CND norm values developed were difficult to comprehend compared to nutrient concentrations, expressed as per cent or ppm (Anjaneyulu *et al.*, 2008). Therefore, the CND norms are having higher diagnostic precision (Parent and Dafir, 1992) compared to the bivariate diagnosis and recommendation integrated system (Walworth and Sumner, 1987).

**Table 4: CND Norms for the selected varieties**

|                 | JASMINE     |       | GIZA        |       | FARO <sub>44</sub> |       |
|-----------------|-------------|-------|-------------|-------|--------------------|-------|
| CND<br>VARIATE  | CND<br>NORM | SD    | CND<br>NORM | SD    | CND<br>NORM        | SD    |
| V <sub>N</sub>  | 3.630791    | 0.127 | 3.88394     | 0.209 | 3.951764           | 0.004 |
| V <sub>P</sub>  | 2.219179    | 0.048 | 2.220435    | 0.269 | 2.084497           | 0.08  |
| V <sub>K</sub>  | 4.225498    | 0.023 | 4.235338    | 0.271 | 4.192926           | 0.067 |
| V <sub>Ca</sub> | 2.269189    | 0.022 | 2.325795    | 0.279 | 2.271708           | 0.096 |
| V <sub>Mg</sub> | 1.64666     | 0.042 | 1.727958    | 0.284 | 1.69363            | 0.072 |
| V <sub>Fe</sub> | -2.51996    | 0.069 | -2.65662    | 0.303 | -2.71055           | 0.035 |
| V <sub>Zn</sub> | -3.71935    | 0.021 | -3.6818     | 0.293 | -3.53581           | 0.052 |
| V <sub>Cu</sub> | -2.32555    | 0.053 | -2.44987    | 0.307 | -2.5331            | 0.072 |
| V <sub>Mn</sub> | -2.65706    | 0.027 | -2.6881     | 0.249 | -2.57321           | 0.083 |
| V <sub>B</sub>  | -2.76939    | 0.153 | -2.91709    | 2.433 | -2.84185           | 0.118 |

**CND Indices**

Independent values were introduced from low yielding rice crops for the purpose of diagnosis of a nutrient that limits the yield. The CND indices identified N as the most common yield limiting nutrients of Jasmin and faro 44, and Zn limiting yield of Faro 44, (Table 5). Among the selected varieties of low yielding rice, both N and Zn were common yield limiting nutrients. Similarly, the results are in conformity with the findings of Anjaneyulu (2007) in which Zn and K were identified as common yield limiting nutrients in papaya diagnosis and recommendation integrated system (DRIS) technique. Boron and Copper were also found to be low in some varieties as reflected through indices (Anjaneyulu and Raghupathi, 2010). However, no single nutrient was found solely responsible for low yield (Anjaneyulu *et al.*, 2008). The concentration of N when below the critical level manifested visual symptoms of nutritional imbalance, which exhibited negative indices. Thus, the yield limiting nutrients were differing from variety to variety though some of the nutrients were more prominent. The order in which nutrients were limiting the yield indicated that most often more than one nutrient was limiting the yield. Among different nutrient elements, Mg showed a significant positive relationship (Table 5) with both K and Cu, whereas N whose requirement is very high for crops like rice showed negative relationship with Zn.

**Table 5: CND Indices for the selected varieties**

| CND INDICES     | JASMIN   | GIZA     | FARO 44  |
|-----------------|----------|----------|----------|
| I <sub>N</sub>  | -0.0591  | 0.554736 | -0.78905 |
| I <sub>P</sub>  | 0.468707 | 0.893809 | -1.12127 |
| I <sub>K</sub>  | 1.148144 | 0.717113 | -0.50008 |
| I <sub>Ca</sub> | 0.27821  | 0.56199  | -0.94594 |
| I <sub>Mg</sub> | 1.050421 | 0.341402 | 0.634753 |

| CND INDICES     | JASMIN   | GIZA     | FARO 44  |
|-----------------|----------|----------|----------|
| I <sub>Fe</sub> | -0.95866 | 0.634927 | 0.913588 |
| I <sub>Zn</sub> | -0.95789 | 0.495567 | -0.15965 |
| I <sub>Cu</sub> | -1.09866 | 0.609554 | 1.140609 |
| I <sub>Mn</sub> | -0.84586 | 0.505641 | 1.145924 |
| I <sub>B</sub>  | 0.1538   | -0.59889 | 0.069321 |

## Conclusion

The study revealed that the application of CND has significant effects on the productivity of rice. The CND norms were effective in determining the nutrient up taken by the three varieties of rice where the norms derived indicated higher requirement of K compared to N that might be due to continuous flowering in rice. The CND indices were effective in establishing the three varieties of rice with nutritional status of N, P, K, Ca, Mg, B, Cu, Fe, Mn, and Zn as sub-optimal, excessive, or balanced concentrations. The CND methodology established the critical level and the appropriate nutrient bands in the current yield basis of rice (*Oryza sativa*). The multi-nutrient associations were more effective than the single nutrient analysis in expressing that the limitation of a given element can reduce the three varieties of rice yield.

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## Avian Diversity in Audu Bako Zoological Garden, Kano State, Nigeria

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### Abstract

Zoological gardens play crucial role in maintaining avian diversity, emphasizing their value in urban biodiversity conservation amidst growing urbanization. The study assessed avian species abundance, distribution and diversity in Audu Bako Zoological Garden, using the line transect method. A total of 2300 individuals belonging to 23 species and classified into 19 families were recorded. Laughing dove (27.26%) and long tailed glossy starling (17.09%) were the highest occurring birds. Columbidae (2), Sturnidae (2) and Lybiidae (2) had the highest numbers of species represented. The majority of bird species were recorded in the wetland habitat (58%), followed by the plain area (28%) and forest habitat (22%). Highest diversity and evenness were recorded in the forest habitat (2.82, 0.90) followed by wetland habitat (2.60, 0.83) and plain area (2.26, 0.72). These findings highlight the importance of the zoological garden in serving as a safe haven for bird species, emphasizing its significance in conserving birds' species. Survey of nocturnal avian species and implementation of appropriate conservation measures are recommended.

**Keywords:** Avian Diversity, Zoological Garden, Specie Abundance Urbanization, Habitat Types.

### Introduction

Birds are one of the most common faunas in all ecological habitats. Owing to their responsiveness to ecological changes, avifauna diversity and distribution are considered as important indicators to evaluate ecological trends of an area (Mistry et al., 2008; Musa et al; 2025). Among the wildlife resources, about 690 species of birds occupy a vital position for their contribution to ecological, economic and cultural sectors of the ecosystem (Gatesire et al. 2014). Forest is the most significant habitat for maintaining the most complex bird community structure. However, this natural habitat of birds has been threatened by human interferences, such as wanton deforestation for urbanization (Shah et al., 2022). Urbanization is an expanding process worldwide, causing major threats to biodiversity through both biotic homogenization and species extinction (Filloy et al., 2018). As global human population continues to increase, current trends and projections indicate that the population of people living in urban areas will nearly double to around 6.5 Billion by 2050 (CBD, 2012). Mills (1989), as cited by Chanda (2023) reported that urbanization and