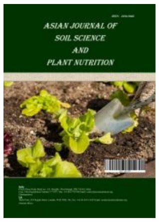


*Asian Journal of Soil Science and Plant Nutrition*

*6(3): 8-17, 2020; Article no.AJSSPN.58210*
*ISSN: 2456-9682*

# Evaluating the Effectiveness of Some Productivity Models on Floodplain Soils of Wukari Area, Northern Guinea Savanna, Nigeria

**A. T. Gani[1*], A. Ali[2], P. I. Agber[2] and S. O. I. Abagyeh[2]**

*[1]Department of Soil Science and Land Resource Management, Federal University, Wukari, Nigeria.*
*[2]Department of Soil Science, College of Agronomy, University of Agriculture, Makurdi, Benue State, Nigeria.*

***Authors' contributions***

*This work was carried out in collaboration among all authors. Author ATG designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors AA and PIA managed the analyses of the study. Author SOIA managed the literature searches. All authors read and approved the final manuscript.*

***Article Information***

DOI: 10.9734/AJSSPN/2020/v6i330089
*Editor(s):*
(1) Dr. Kosev Valentin, Institute of Forage Crops, Bulgaria.
*Reviewers:*
(1) Juscélia da Silva Ferreira, Federal University of Pernambuco, Brazil.
(2) Yonnas Addis Mihretie, Wokite University, Ethiopia.
Complete Peer review History: http://www.sdiarticle4.com/review-history/58210

***Original Research Article***

***Received 20 April 2020***
***Accepted 26 June 2020***
***Published 10 July 2020***

## ABSTRACT

A study on quantifying the productivity of Wukari flood plain soils using Neill's Productivity Index (PI), Modified Neill's Productivity Index (PIm) and Riquier Productivity Index (RI) was carried out. The applicability and validity of the productivity index models were determined using rice as a test crop. Result showed significant relationships with coefficients of determination ($R^2$) of 0.7158, 0.7204 and 0.8778 found between grain yield of rice (Y) and PI, PIm and RI values respectively. The highest and the lowest grain yield of rice to a reasonable extent correspond to the higher and the lower productivity index values, respectively. Higher productivity indices explained higher mean grain yield of rice. The productivity indices values decreased with the decrease in grain yield. The grain yield of grain followed productivity index predictions and are hereby recommended as tools of soil productivity assessment in the study area.

**Corresponding author: Email: adashutanko@yahoo.com;*

*Keywords: Flood plains; productivity index; soil productivity; rice; model.*

## 1. INTRODUCTION

Floodplains have reported to be fragile ecosystems and their conversion to cropland may result in severe ecological and environmental deterioration and degradation if not appropriately done [1]. However, increasing demand for food as a result of rapid population expansion in Nigeria necessitates a substantial extension of croplands into some hitherto uncultivated wetlands/floodplains otherwise considered as marginal lands for rain-fed agriculture [2,3]. Basic soil resource information a pre-requisite for planning sustainable agriculture [4,1] and sustainable agriculture requires both direct and indirect knowledge of the capability and nutrient status of the soils to be utilized [5].

In Nigeria, low soil nutrient reserve due to the predominance of low activity clays and declining soil fertility have been one of the major problems of smallholder farmers, but [2], opined that soil fertility replenishment strategy that could allow for a sustainable agricultural productivity has not been developed. The need for soil surveys and land evaluation reports prior to crop cultivation and other agricultural land uses have been emphasized [6]. However most land evaluation studies are executed by Pedologists who view the soil as embodiment of pedogenic processes and more emphasis are laid on soil genesis, inherent characteristics and taxonomy; the interpretations of the soil data in land evaluations are based on perceived or expected land developments.

Accurate estimate of future soil productivity is essential to make agricultural policy decisions and to plan the use of land from field scale to the national level. According to [7], Productive soils contribute to the Production of food, fuel, fibre and building mateials. The importance of these products are evident in structured markets. Maintaining productive soils is important in lowering the cost of production and minimizing human inputs such as pesticides and fertilizers [8,9]. Similarly, relationship between soil properties and soil's capacity for producing plants or soil productivity is today the focus of a number of research projects [10,11]. The projects according to [12] have grown out of a need to increase the knowledge of quantitative relationships between plant growth and soil properties.

Over the years, various approaches that attempt to numerically relate soil properties to its productivity are developed [13]. These approaches include the Universal Soil Loss Equation (USLE) and Erosion Productivity Impact Calculation (EPCI) [8]. However, a simple numerical index model is now preferred to others because of its simplicity and applicability in many soils [13]. The model widely used today in quantification of soil productivity is the productivity index (PI) model modified by [14]. This productivity index is based on the use of physical and chemical properties to predict effect of soil erosion on productivity [14]. Productivity index is an algorithm based on the assumption that crop yield is a function of root growth which includes rooting depth as controlled by soil environment [15].

The productivity of soil is reduced though soil degradation in form of erosion, contamination, deforestation and dissertation [16,11]. The reduction may manifest as soil constraints such as loss of plant nutrients, loss of storage capacity for plant-available water, degradation of soil structure and decreased uniformity of soil conditions within a field [16]. Soil productivity constraints in tropical Africa have been grouped into four broad categories by [7] as nutrient availability and retention, nutrient toxicities, water availability and physical degradation.

While floodplains in river basins of many parts of the world are used for agriculture because of their natural fertility [17]. [1] observed that some promising *Fadama* soils were poorly managed and have been abandoned by cultivators because of soil fertility decline, erosion and desiccation. Land evaluation using a scientific procedure, is essential to assess the potential and constraints of a given land for agriculture purposes and the knowledge of soil limitation arising from land evaluation report therefore aims at providing practical approaches to ameliorating such limitations before or during cropping period [18]. Appropriate protection and judicious utilization of the floodplains is essential to enable this ecosystem continue to provide livelihood to local community. Also sustainable agricultural production can only be achieved when information on the soil characteristics are carefully collected, assembled and interpreted. This study was carried out therefore to characterize the soils of the floodplains and evaluate the agricultural productivity of the soil using some productivity models.

## 2. MATERIALS AND METHODS

### 2.1 Site Description and Location

The experiment was carried out at the floodplain soils of Gidan Idi, Gindin Dorowa, Tsokundi, RafinKada and Nwuko which are located in Wukari Local Government Area of Taraba State, Nigeria. Wukari Local Government Area lies on latitude 7°51'N and longitude 9°47'E. Total land area is 4,308 $km^2$ (1,663.3 sq miles) and total population is 241,546 by the 2006 census. Wukari Local Government Area is located in the Northern Guinea Savannah agro-ecological zone of Nigeria and has 2 distinct seasons; wet and dry. The wet season starts from April and ends in October, with mean Annual rainfall of 1300 mm and mean air temperature of 28°c. Wukari Local Government Area has common boundaries with: Ibi local government area to the North-West; Gassol Local Government Area to the North-East; Donga Local Government Area to the South-East; and Benue State to the South-West. The common tillage practices in the rice soils include animal tractions by use of ox-drawn plough and tractor mounted harrows. The common crop grown is rice. Secondary crops include sugar cane, vegetables (Onions, pepper, greens) and maize. Fishing activities (such as cat fish, lung fish) and brick making are common place.

### 2.2 Field Methods

Sites in the flood plains which are heavy soils with high water holding capacities were selected for the five sites for growing rice. Composite soil samples were collected with soil auger at 0-20 20-40 and 40-60 cm depths for routine analysis before planting in 2016. The samples were taken for laboratory analyses. Furthermore, auger and Core samples were collected at 0-20 cm, 20-40 cm and 40-60 cm depths in each plot after harvest in 2016 and 2017 respectively for analyses of physicochemical properties.

The land was ploughed once and harrowed twice to provide sufficient tilth for rice growth. This was done before the first rain. Rice (Faro 44 - sipi 6920233) hybrid variety was used as a test crop. The early maturing rice variety, Faro 44 (sipi 6920233) rice seed was collected from the Liaison Office of the Value Chain Development Project Wukari for planting. Planting was by direct seeding. Plating depth was 2-4 cm (pre germinated seeds in wet soils). Dibble 5-6 seeds at a spacing of 25 cm×20 cm intra row which was later thinned to 3-4 seedlings per stand at 3-4 weeks after sowing. Recommended fertilizer rate of 120 kg N, 40 kg $P_2O_5$ and 40 kg $k_2O$ per ha was applied at 30, 60 and 80 days after planting by top dressing method.

Hand weeding was done regularly especially during early stages of growth, that is, the first weeding was done 2-3 weeks after emergence using hoes and hand pulling and the second weeding was done 5-6 weeks after emergence.

Harvesting was done when 80-85% of the grains turned straw colour to avoid shattering (i.e. 4-5 weeks after 50% flowering). The rice stem was cut with sickle at about 15-20 cm above the ground (to permit hand threshing). The panicles was tied in bundles and heaped for drying before threshing 80% of the paddy. The rice was dried to 12-14% moisture content before threshing.

### 2.3 Laboratory Methods

The collected samples were used to determine soil physical and chemical properties. Particle size distribution was determined by Bouyoucos hydrometer method of mechanical analysis [19]. The bulk density was determined by the core Method of known soil volume [20]. Available water capacity was determined with pressure plate apparatus as described by [21]. Soil pH was measured electrometrically using glass electrode pH meter in a soil-water ratio of 1:2.5 [22]. Total nitrogen was determined by micro-Kjeldahl digestion technique method [23]. Exchangeable bases were determined by the neutral ammonium acetate procedure buffered at pH 7.0 [24]. Exchangeable acidity was got by a method described by [25]. Total carbon was analyzed by wet digestion and the organic carbon content was multiplied by a factor (1.724) to get the percentage organic matter (Nelson and Sommers, 1982). Available phosphorous was determined by Bray II method according to the procedure of [26]. Cation Exchange Capacity was determined using neutral ammonium acetate leachate method [27]. Base saturation was computed as Total exchangeable bases divided by Cation Exchange Capacity. Extractable iron and aluminium were determined by the sodium citrate, sodium bicarbonate and sodium dithionite (CBD) method described by [28].

## 2.4 Grain Yield

The clean grains obtained after threshing and winnowing from the net plot area of each plot were weighed on an electronic balance. After this, the grain yield (kg) per plot was converted into grain yields (kg) per hectare by multiplying with an appropriate conversion factor (367.65).

## 2.5 Productivity Index Model

### 2.5.1 Application of the Neill's productivity index (PI) model

The Neill Productivity Index (PI) model modified by [14] was used. This model was based on simple measurable soil properties. The expression is:

$$PI = \sum_{i=1}^{n} A_i \times C_i \times D_i \times F_i \times L_i \times J_i \times Wf_i$$

Where;

PI = Productivity Index
$A_i$ = Sufficiency for available water capacity for the ith soil layer.
$C_i$ = Sufficiency for pH for the ith soil layer.
$D_i$ = Sufficiency for bulk density for the ith soil layer.
$F_i$ = Sufficiency for clay content for the ith soil layer.
$L_i$ = Sufficiency for land slope for the ith soil layer.
$J_i$ = Sufficiency for organic matter content for the ith soil layer.
$Wf_i$ = Root weighting factor (based on depth of root zone).
n = Number of horizons in the rooting zone (soil layer).

### 2.5.2 Application of the modified Neill's productivity index (PIm) model

The PI model developed by Pierce et al. [14] was expanded to capture the influence of phosphorus (P), iron oxide (FeO) and aluminum oxide ($Al_2O_3$) by [29] as follows:

$$Pm = \sum_{i=1}^{n} A_i \times C_i \times D_i \times F_i \times L_i \times J_i \times Wf_i \times Pi \times Fei \times Ali$$

Where;

PIm= Modified Neill productivity index
$A_i$ = sufficiency for available water capacity for the ith soil layer.
$C_i$ = sufficiency for pH for the ith soil layer.
$D_i$ = sufficiency for bulk density for the ith soil layer.
$F_i$ = sufficiency for clay content for the ith soil layer.
$L_i$ = sufficiency for land slope for the ith soil layer.
$J_i$ = sufficiency for organic matter content for the ith soil layer
$Wf_i$ = root weighting factor (based on depth of root zone)
n = number of horizons in the rooting zone (soil layer)
$P_i$ = sufficiency for phosphorus content for the ith soil layer.
$Fe_i$ = sufficiency for iron oxide content in the ith soil layer
$Al_i$ = sufficiency for aluminum oxide content in the ith soil layer

### 2.5.3 Application of the Riquier productivity index (RI) model

The productivity index model adopted for this study as defined by [30] is given as:

$$Pa = H \times D \times P \times T \times Fa$$

Where;

Pa = soil productivity
H = soil moisture based on the number of wet/dry months
D = Drainage
P = Effective soil depth (rooting zone)
T = soil texture/structure
Fa = Actual Fertility Index.

But,

$$Fa = O \times pH \times N \times C \times S$$

Where;

O = Organic matter,
pH = soil reaction,
N = base saturation,
C = Nature of clay taken as CEC per kg clay,
S = soluble salts contents.

## 2.6 Data Analysis

Productivity index was determined by calculating soil sufficiency values. Correlation analysis was used to determine the relationship between soil properties and grain yield of rice according to [31].

## 3. RESULTS AND DISCUSSION

### 3.1 Properties of the Flood Plain Soils

Tables 1 and 2 show the average soil property, ascribed sufficiency values and predicted productivity indices of the soils. Generally, the mean values of the soil textural analysis indicate that the clay fraction dominated the fine earth separate. This was closely followed by the sand fraction, while the silt fraction was the lowest. The soil textures in these areas are mainly clay loam, which is medium texture. Bulk density of the flood plains had lowest mean value of 1.31 g/cm$^3$ and highest mean value of 1.318 g/cm$^3$. These values also agree with [32] that density of clay loam surface normally ranged from 1.00 to 1.60 g/cm$^3$. The bulk density values of the flood plains were lower than 1.6 g/cm$^3$, thus rated medium, a range considered not to impede root penetration [33]. The lowest value of mean available water capacity recorded in the flood plains is 0.259 m/m while the highest mean value is 0.263 m/m. Generally, the available water capacity of these soils is low.

The soils of the flood plains had mean pH values range from 6.650 to 7.082. Soil reaction was slightly acidic to neutral [34]. The soils organic matter (OM) contents of the flood plains had highest mean value of 2.641% and lowest mean value of 2.459%. Organic matter is generally low in the soils according to [35], ratings ( >20% very high, 10-20% high, 4-10% medium, 2-4% low and < 2% very low). The available phosphorus content of these soils is high with highest mean value of 16.740% and lowest mean value of 15.218%. These high values may be due to the fact that phosphorus is characteristically immobile, and tend to remain fixed at the surface.

The exchangeable bases comprised of exchangeable calcium, magnesium, potassium and sodium. Calcium was the dominant exchangeable base in all the soils. The exchangeable calcium (Ca) in the flood plains was rated medium range, the range in value of magnesium were moderate, potassium values were generally in the medium range and sodium values were generally in the medium range. Generally, the exchangeable bases occurred in the order Ca>Mg>K>Na in all the flood plains, this corroborates earlier reports on soils of the Nigerian savannah [36]. The exchange acidity comprises exchangeable hydrogen and exchangeable aluminium. The values were classified as generally in the medium range which suggests that the soils have little or no acidity problems, except for incipient acidity in some horizons. The cation exchange capacity of Wukari flood plains were rated medium based on the findings of [37] who reported cation exchange capacity values of < 6, 6 - 12 and > 12 cmol(+)/kg as low, medium and high respectively. Base saturation (BS) of the flood plains had highest mean value of 55.90% and lowest mean value of 53.69%. The values were rated moderate being generally between 50 and 80%. The medium values indicate that the soils have moderate potentials for supplying plant nutrients; hence, the necessity for adequate soil management, most especially the upland.

The highest mean value of the extractable iron oxide content of the flood plains was 4.567 g/kg and the lowest mean value of the extractable iron oxide content of the flood plains was 3.911 g/kg. The value of the extractable iron oxide content of the flood plains is generally low and appears to indicate that low amounts of extractable iron is contained in the fluviatile soil parent material from which the soils are presumed to be derived. The values of extractable aluminium oxide obtained in the floodplains are low. It is possible that aluminium oxides in these soils have been depleted and used for clay formation by neoformation such that only trace amounts of extractable aluminium oxide is left in the soil. Such clays that may have formed in these soils include kaolinite, illite and smeotite.

### 3.2 Soil Productivity Index and Ascribed Sufficiency Values

Tables 1 and 2 show the average soil properties, ascribed sufficiency values and predicted productivity indices of the soils. The physical and chemical properties of the studied soils were used to quantify the productivity of the floodplain soils. The sufficiency of the soil properties for each floodplain location was multiplied and summed to the number of depth increments (n) to estimate the PI, PIm and RI, where, a value of zero indicates an absolutely limiting level of a soil property and a value of 1.0 indicated the optimum level [38]. According to [11], high soil productivity index is a good indicator of soil capacity to support crop production for long period of time.

#### 3.2.1 The Neill's productivity indices (PI and PIm)

Values of the productivity indices (PI and $PI_m$) are given in Table 1. The data showed that the mean values of PI calculated were 0.413, 0.422, 0.446, 0.432 and 0.418 for Nwuko, Tsokundi, Rafin-Kada, Gidan-Idi and Gindin-Dorowa floodplains respectively and the mean values of $PI_M$ calculated were 0.248, 0.270, 0.279, 0.276 and 0.267 for Nwuko, Tsokundi, Rafin-Kada, Gidan-Idi and Gindin-Dorowa floodplains respectively. The variation in PI values is depending on the initial properties of each soil, within the root zone, which affect the sufficiency of each soil property. The PI values were obviously higher than those values of $PI_m$. These results showed that when three more parameters, i.e. available phosphorus (P), iron oxide (FeO) content and aluminium oxide ($Al_2O_3$) content were included in the model, the values of PIm decreased as compared with PI values.

Contributions of iron and aluminium oxides to the soil productivity are decreasing with their contents. The sufficiency of iron and aluminium oxides are low therefore, restricted the soil productivity. The results also showed that the highest mean $PI_m$ of 0.279 was obtained in Rafin-Kada floodplain while the lowest mean $PI_m$ of 0.248 was obtained in Nwuko floodplain. High productivity index indicated soil with improved soil properties; therefore, the most productive soil is Rafin-Kada floodplain soil.

#### 3.2.2 The Riquier's productivity index (RI)

The Riquier's productivity index (RI) values are given in Table 2. The mean values of RI calculated were 0.192, 0.196, 0.200, 0.198 and 0.194 for Nwuko, Tsokundi, Rafin-Kada, Gidan-Idi and Gindin-Dorowa floodplains respectively. The results showed that the variation in soil organic matter content reflected on RI values. The RI values increased as soil organic matter content increased.

### 3.3 Rice Grain Yield per Hectare within the Study Locations

The grain yield of rice (t/ha) is shown in Table 3. The results of rice plant yield parameters analysed from the flood plains show that Nwuko flood plain had mean grain yields of 7.42 t/ha in 2016 and 7.82 t/ha in 2017; Tsokundi flood plain had mean grain yields of 8.33 t/ha in 2016 and 7.84 t/ha in 2017; Rafin-Kada flood plain had mean grain yields of 7.36 t/ha in 2016 and 8.02 t/ha in 2017; Gidan-Idi flood plain had mean grain yields of 8.00 t/ha in 2016 and 8.33 t/ha in 2017 and Gindin-Dorowa flood plain had mean grain yields of 7.92 t/ha in 2016 and 7.41 t/ha in 2017.

The highest mean rice grain yield of the flood plains was 8.36 t/ha at Rafinkada in 2016 and the lowest mean rice grain yield of the flood plains was 7.41 t/ha at Gidan Idi in 2017. The ANOVA showed that rice grain yield of the floodplains were significantly different for the different locations investigated at $P \leq 0.05$ level of significance in 2016 but were not significantly different for the different locations investigated at $P \leq 0.05$ level of significance in 2017. The means separation using F-LSD at 0.05 probability levels showed that the differences among some of the mean rice grain yield of the floodplain locations are statistically significant.

### 3.4 Individual Productivity Index and Grain Yield of Rice

Grain yields of rice of the different floodplain locations and their corresponding productivity indices are shown in Table 4. The highest and the lowest grain yield of rice to a reasonable extent correspond to the higher and the lower productivity index values, respectively. Higher productivity indices explained higher mean seed yield of rice. The productivity indices values decreased with the decrease in seed yield. These data suggest that differences in crop yield can be represented by productivity indices values. This finding agreed with [3] and [39] who found that corn yield increased with the increase of PI and decreased with the decrease of it. The results concluded that as PI, PIm and RI values decreased a general decline in grain yield of rice is recorded.

### 3.5 Relationship between Productivity Index and Grain Yield of Rice

The result on Table 5 shows the relationship between productivity index and grain yield of rice. Crop yields are usually used as a measure of soil productivity, therefore, the relationship between rice yield and productivity indices were obtained. Significant relationships with coefficients of determination ($R^2$) of 0.7158, 0.7204 and 0.8778 found between grain yield of rice (Y) and PI, PI and RI values respectively as follows:

$$Y = 0.143 + 18.332\ PI$$
$$Y = 2.646 + 19.814\ PIm$$
$$Y = -\ 8.508 + 84\ RI$$

**Table 1. Soil properties, ascribed sufficiency and calculated Neill's productivity index (PI and PIm)**

| Soil property | Location | | | | | Ascribed sufficiency | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Nwuko | Tsokundi | Rafin-Kada | Gidan-Idi | Gindin-Dorowa | Nwuko | Tsokundi | Rafin-Kada | Gidan-Idi | Gindin-Dorowa |
| AWC (m/m) | 0.261 | 0.259 | 0.262 | 0.260 | 0.263 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| pH ($H_2O$) | 6.886 | 7.082 | 6.657 | 6.650 | 6.713 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Bulk density (g/cm$^3$) | 1.318 | 1.307 | 1.321 | 1.311 | 1.313 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |
| Clay content (%) | 36.856 | 36.600 | 36.344 | 36.756 | 37.233 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Land slope (%) | 2 | 2 | 2 | 2 | 2 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Organic matter (%) | 2.459 | 2.580 | 2.641 | 2.602 | 2.542 | 0.86 | 0.88 | 0.93 | 0.90 | 0.87 |
| Root weighting factor (cm) | 60 | 60 | 60 | 60 | 60 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 |
| Phosphorus (%) | 16.608 | 15.218 | 16.556 | 16.692 | 16.740 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Iron oxide (g/kg) | 4.000 | 4.511 | 3.911 | 4.567 | 4.500 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |
| Aluminum oxide (g/kg) | 0.878 | 0.744 | 0.833 | 0.778 | 0.767 | 0.75 | 0.8 | 0.78 | 0.8 | 0.8 |
| Calculated PI | | | | | | 0.413 | 0.422 | 0.446 | 0.432 | 0.418 |
| Calculated PIm | | | | | | 0.248 | 0.270 | 0.279 | 0.276 | 0.267 |

**Table 2. Soil properties, ascribed sufficiency and calculated Riquier's productivity index (RI)**

| Soil property | Location | | | | | Ascribed sufficiency | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Nwuko | Tsokundi | Rafin-Kada | Gidan-Idi | Gindin-Dorowa | Nwuko | Tsokundi | Rafin-Kada | Gidan-Idi | Gindin-Dorowa |
| Soil moisture | Rooting zone below wilting point for 5 months | | | | | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 |
| Drainage | Water logging for brief period (flooding) | | | | | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 |
| Effective soil depth | Fairly deep soil, 60 – 90 cm | | | | | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 |
| Soil texture/structure | **Massive to large prismatic structure** | | | | | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 |
| Organic matter (%) | 2.459 | 2.580 | 2.641 | 2.602 | 2.542 | 0.93 | 0.95 | 0.97 | 0.96 | 0.94 |
| pH ($H_2O$) | 6.886 | 7.082 | 6.657 | 6.650 | 6.713 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Base saturation (%) | 53.94 | 53.69 | 54.51 | 55.17 | 55.90 | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 |
| Exchangeable capacity of Clay (Cmol(+)Kg$^{-1}$) | 11.044 | 10.623 | 10.74 | 10.922 | 10.840 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 |
| Total soluble salts (%) | 0.233 | 0.230 | 0.228 | 0.240 | 0.228 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 |
| Calculated RI | | | | | | 0.192 | 0.196 | 0.200 | 0.198 | 0.194 |

**Table 3. Grain yield (t/ha)**

| Locations | Year | |
|---|---|---|
| | **2016** | **2017** |
| Nwuko | 7.43 | 7.82 |
| Tsokundi | 8.33 | 7.84 |
| Rafin-Kada | 8.36 | 8.07 |
| Gidan-Idi | 8.00 | 8.33 |
| Gindin-Dorowa | 7.92 | 7.41 |
| F-LSD $_{0.05}$ | 0.598 | - |

**Table 4. Productivity index and rice grain yield**

| Locations | PI | PIm | RI | Grain yield (t/ha) |
|---|---|---|---|---|
| Nwuko | 0.413 | 0.248 | 0.192 | 7.63 |
| Tsokundi | 0.422 | 0.270 | 0.196 | 8.09 |
| Rafin-Kada | 0.446 | 0.279 | 0.200 | 8.22 |
| Gidan-Idi | 0.432 | 0.276 | 0.198 | 8.17 |
| Gindin-Dorowa | 0.418 | 0.267 | 0.194 | 7.67 |

**Table 5. Relationship between productivity index and rice grain yield**

| Productivity index | Regression model | Coefficient of determination ($R^2$) | Correllation coefficient (R) |
|---|---|---|---|
| PI | Y = 0.143 + 18.332 PI | 0.7158 | 0.8460 |
| PIm | Y = 2.646 + 19.814 $PI_M$ | 0.7204 | 0.8488 |
| RI | Y = -8.508 + 84 Pa | 0.8778 | 0.9369 |

From the regression results, PI, PIm and RI models could explain about 71.58, 72.04 and 87.78% of grain yield variations respectively. This result proves that PI, PIm and RI models are good yield prediction models. This finding indicates that productivity index could indeed be used to predict grain yield of rice and by extension other crops. This result is supported by the report of [39] where he observed that productivity index was a veritable tool for quantifying soil productivity.

### 3.6 Evaluation of Soil Productivity

Evaluation of soil productivity was done according to [40]. Comparing the calculated PI, PIm and RI values with the relative data of productivity index, the productivity of floodplain soils obtained with PI is high (0.31 – 0.50) whereas, with $PI_m$ and RI all the floodplain soils have moderate productivity (0.11 – 0.30) [40].

The results showed that PI values were higher than PIm and RI values; therefore, the PIm and RI models did not reflect the actual productivity level. Productivity index (PI) provides a single scale on which soils may be rated according to their suitability for crop production. The results indicated that soil physical and chemical properties could be limiting or non-limiting factors on the productivity of soils. The changes in soil organic matter content influenced PI values. The PI model was able to demonstrate 71.58% of the variations in seed yield ($R^2$= 0.7158).

## 4. CONCLUSION

The result of this study indicated that productivity of Wukari flood plain soils could be quantified. Sufficiency values of soil properties such as available water capacity, bulk density, rooting depth and soil pH could be used to quantity productivity index of soil. Furthermore, productivity index has direct reciprocal relationship to a great extent with yield of crops. Wukari flood plain soil gave a highly significant relationship between productivity index and grain yield of rice.

The Productivity Models (PI, PIm, RI) tested were all found to be effective in assessing Soil Productivity of the floodplains and hereby recommended as a tool for Soil Productivity Assessment in the study area.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

## REFERENCES


1. Babalola TS, Oso A, Fasina S, Godonu K. Evaluation studies of two wetland soils in Nigeria. International Research Journal of Agricultural Science and Soil Science. 2011;16:193-204.
2. Ojanuga AG. Agro-ecological zones of Nigeria manual. FAO (NSPFS, Federal Ministry Agriculture and Rural Development, Abuja, Nigeria). 2006;124.
3. Nwite JN. Evaluation of the productivity of automobile oil contaminated soil amended with organic wastes in Abakaliki, Southeastern Nigeria. Ph.D Thesis, University of Nigeria, Nsukka. 2013;1-130.
4. Ekwoanya MA, Ojanuga AG. Productivity assessment of upland and flood plain soils at Makurdi, Nigeria. Geoderma. 2002;108:19-20.
5. Dickson AA, Allison O, Isirimah NO. Fertility capability classification based land evaluation in relation to socio-economic conditions of small holder farmers in Bayelsa State of Nigeria. Indian Journal of Agricultural Science. 2002;36(1):10-16.
6. Orimoloye JR. Characterisation and evaluation of selected soils of Southern Nigeria for Rubber (*Hevea brasiliensis*, Muell. Arg) cultivation. Ph.D. Thesis, University of Ibadan, Ibadan. 2011;238.
7. Wommer PL, Muhena FN. Overcoming soil constraints in crop production in Tropical Africa. In: Sustaining Soil Productivity in Intensive African Agriculture. Proceedings of Agricultural Association in Tropical Africa 15-19 November, Accra Ghana; 1993.
8. National Soil Erosion and Productivity Research Planning Committee. Soil erosion Mba effects on soil productivity. A research perspective. Journal of Soil and Water Conservation. 1981;36:82-90.
9. Brady NC, Weil RR. The nature and properties of soil. New Jersey, Pearson Education, Inc. 2002;837.
10. Follet RF, Stewart BA. Soil erosion and crop production. Wisconsin, Madison, USA; 1985.
11. Nwite JN, Obi ME. Quantifying the productivity of selected soils in Nsukka and Abakaliki, Southeastern Nigeria using productivity index. Agro-Science. 2008;7(3):170-178.
12. Gantzer C, McCarty TR. Predicting corn yields on clay using soil productivity index. American Society of Automobile Engineers. 1987;30:1347-1352.
13. Anikwe MAN. Use of numerical index methods for quantifying the productivity of some soils in Southeastern Nigeria. Ph.D Thesis, University of Nigeria Nsukka. 2000;89.
14. Pierce FJ, Larson WE, Dowdy RH, Graham WAP. Productivity of soils. Assessing long term changes due to erosion. Journal of Soil and Water Conservation. 1983;38:39-44.
15. Lindstorm MJ, Schumacher TE, Jones AJ, Gantzer C. Productivity index and model comparison for selected soils in North Central United States. Journal of Soil and Water Conservation. 1992;47(6):491-494.
16. Williams JR, Sharpley AN, Taylor D. The erosion productivity impact calculator. In: Boardman, J., Foster, I.D.L. and Dearing, J.A. (Eds). Soil Erosion on Agricultural Land. John Wiley and Sons, New York; 1990.
17. Verhoeven JTA, Setter TL. Agricultural use of wetlands; Opportunities and limitations. Annals of Botany. 2010;105:155-163.
18. Lin H, Bourma J, Wilding J, Richardson L, Kutilek M, Nielson DR. Advances in hydropedology. Advances in Agronomy. 2005;85:1-89.
19. Trout TJ, Garcia-Castillas IG, Hart WE. Soil engineering field and laboratory manual. Perks. Indiana. 1987;43-44.
20. Fuller WH, Warrick AW. Soils in waste treatment and utilization. D. R. E. Press. Florida. 1985;1:51.
21. Singh BT, Nandini DK, Bijen KY, Bishworjit N, Nongdren KSL, Herojit SA. Characterization and evaluation for crop suitability in lateritic soils. African Journal of Agricultural Research. 2013;8(37):4628-4636.
22. Hendershot WH, Lalande H, Dequette E. Soil reaction and exchangeable acidity. In: Carter, M.R (Ed). Soil Sampling and Methods of Analysis Canadian Soc. of Sci, Lawis Pub, London. 1993;141-145.
23. Bremner JM. Nitrogen total. In Sparks, D.L. (Ed). Methods of Soils Analysis, Parts Chemical mth 2$^{nd}$ Ed, SSSA Book Series No. 5, SSSA, Madison WI. 1996;1085-1125.
24. Thomas GW. Exchangeable bases. In: Methods of Analysis Part 2. Page A.L, Miller, R.H. and Keeney D.R. (Eds). American Society of Agronomy Madison Wisconsin. 1982;159-165.

25. McLean EO. Soil pH and lime requirement. In: Methods of soil analyses. Part II. Agronomy 9th Ed' A. L. Page. Am. Soc. of Agronomy Madison Wisconsin. 1982;199-234.
26. Nelson DW, Sommers LE. Total carbon, organic matter. In: Pages AL, Miller RH and Kenney DR (Eds). Methods of Soil Analysis, Part 2 Amer Soc. Agron. Madison, Wis. 1982;539-579.
27. Summer ME, Miller WP. Cation exchange capacity. In: DL Sparks (Eds) Methods of Soil Analysis. Part 2: Chemical Properties, (3rd Ed) ASA, SSSA, CSSA, Madison, W.I. 1996;1201-1229.
28. Parfitt RL, Childs CW. Estimation of forms of Fe and Al: A review and analysis of contrasting soils by dissolution and Moessbauer methods. Australian Journal of Soil Research. 1988;26(1):121–144.
29. Agber PI. Testing the effectiveness of soil productivity assessment models in Makurdi, Benue State, Nigeria. An Unpublished PhD Thesis Submitted to the Department of Soil Science, University of Agriculture, Makurdi, Benue State; 2011.
30. Riquier J, Cornet JP, Bramao DL. A new system of soil appraisal in terms of actual and potential productivity. 1st Approx. World Soil Res. FAO, Rome, Italy. 1979;44.
31. Steel GD, Torrie JH. Procedures of statistics. A biometrical approach 2nd Ed. New York: McGraw Hill, Book Company. 1980;63.
32. Brady NC. The nature and properties of soils. Macmillan, New York. 1990;621.
33. Donahue RL, Raymond MW, Schick Line JC. Soils: An introduction to soils and plant growth. Prentice Hall of India. 1990;667.
34. Malgwi WB. Characterization of salt affected soils in some selected location in the North Western Zone of Nigeria. An Unpublished PhD Thesis Submitted to Soil Science Department, Ahmadu Bello University, Zaria; 2001.
35. Landon JR. Booker tropical soil manual: A handbook for soil survey and agricultural land evaluation in the tropics and subtropics. New York: McGraw-Hill Pub. Co. 1991;474.
36. Raji BA. Pedogenesis of ancient dune soils in the Sokoto Sedimentary Basin, North Western Nigeria. Unpublished Ph.D. Thesis. Dept. of Soil Science, ABU, Zaria; 1995.
37. Adepetu JA, Aduagi EA, Alofa CA. A preliminary of fertility status of some soils in Ondo State under traditional cultivation. Ife Journal of Agriculture. 1979;134:149.
38. Kiniry LM, Scrivener CL, Keener ME. A soil productivity index based on water depletion and root growth. Res. Bull. 105, Colombia University of Missouri. 1983;89.
39. Anikwe MAN, Obi ME, Agbim NN. Effect of crop and soil management practices on soil compactibility in maize and groundnut plots in a *paleustult* in Southeastern Nigeria. Plant and Soils. 2003;253:457-465.
40. Fernando D. A framework to make decisions in soil conservation for tropical mountains. 17th World Congress of Soil Sci. (WCSS) Thailand Symp. 2002;38.



*Peer-review history:*
*The peer review history for this paper can be accessed here:*
*http://www.sdiarticle4.com/review-history/58210*