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Identification and Validation of Pedochemical and Fertility Indices of Soils Influencing Maize (*Zea mays*) Crop Production in the Rain Forest Agro-ecology of Nigeria

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ABSTRACT

Background: The soil is a fundamental natural resource of any nation hence proper assessment of the kind and extent of this resource is prerequisite to its improvement and rational use.

Methods: Random sampling technique was used to collect soils from each of the 18 LGAs of Cross River State, Nigeria and each separated into two parts. One part was used for the cultivation of local maize while the other part of soil was analysed for pedochemical properties and fertility indices.

Result: The results reveal that organic carbon ranged from 1.40 g/kg^3 to 2.84 g/kg^3. Available Phosphorus varied from 3.31 mg/kg to 29.24 mg/kg. The value of total nitrogen varied from 0.11 g/kg^3 to 0.24 g/kg^3. Cation exchange capacity (CEC) also varied from 7.01 Cmol/kg^3 to 12.01 Cmol/kg^3. The soils across the agroecology were more acidic 5.00 to less acidic 0.61. Boron varied from 0.52 mg/kg^3 to 2.01 mg/kg^3 while Zinc also ranged from 1.93 mg/kg^3 to 5.0 mg/kg^3. The results also show that 33.33% of the soils were rated high, medium and low for available phosphorus. It was identified that total nitrogen nutrient fertility ratings for the soils was 77.78% high fertility ratings and 22.22% medium fertility ratings. Results identified organic carbon fertility rating was of high fertility rating of 72.23% while 27.67% medium rating was identified for organic carbon content. Ten (10) principal components (PC) were identified to contribute to the total 100% support for maize crop production in the study area.

Key words: Chemical properties, Cluster groups, Fertility status, Maize production, PCA, Rain forest.

INTRODUCTION

Most soils in the tropics, especially soils in Cross River rain forest agroecology of Nigeria, are low in plant nutrients to meet crop major requirement (Ubi *et al.*, 2016; Chase *et al.*, 1991). One of the major causes of low yield is inadequate information on the fertility and productive status of soils used for maize cultivation, especially the pedochemical and nutrient indices of the tropical soils (Blacbie, 1993). Several researches have shown that soils rich in pedochemicals releases nutrients to the plant, improves physical properties and enhance growth and development of the crop (Bada *et al.*, 2004).

Maize is a staple grain/cereal crop grown almost in all parts of the world. It is a high yielding cereal grown successfully under rained environment and requires less capital. It has established itself as a very significant component of the farming system and determines the cropping pattern of the predominantly peasant farmers (Gwehengwe *et al.*, 2020; Ayeni *et al.*, 2008). This grain crop is used as human food, animal feed, as well as for industrial usage. Maize can be boiled, roasted or fried while industrially it can be processed to produce cornflakes, golden morn, quaker oat, custard, flour, beer and beverages, as well as animal feed.

In recognition of the remarkable role of maize in staple food supply and its high cultivation and demand, led to the need to increase and expand sustainable production of the crop in the humid agro-ecology of Cross River State, with

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moderately leached acid soils rich in fertility status. Studies and reports by (Agbachom *et al.*, 2022; Adediran and Banjoko, 2003) has shown that soils from the study area are derived from coastal plain sands dominated by quartz, Fe and Al oxides which have significant implications on soil health and productivity. Globally, maize is ranked 3rd after rice and wheat, but in Nigeria and Cross River State, it is one of the most important cereal crop. High demand for maize has made it less affordable for poor consumers, thus the need for increased productivity can never be over emphasized. Reports of (FAO, 1996) shows that there is a decline in worldwide maize production from 1142.3 mt in 2018 to 1098.5 mt in 2019 (6% drop). This according to the report was attributed to continual use of low yielding cultivars, declining soil fertility, productivity and inappropriate use and adoption of improve farming technologies in addition to poor management of soil borne pathogens amongst others (Ubi *et al.*, 2016; Eshiet, 1985).

Statistics had shown that, Nigeria produced 7.2 Million metric ton of maize in 2019/2020 and Cross River State ranks among the top producers. Maize has now risen to a commercial crop on which many agro-based industries depend on for raw materials implying that maize has become the new cash crop for many farmers who now diversify their crops production because of the new trend of market forces. However, (Philip *et al.*, 2010) had observed that the demand for maize exceeds supply as a result of its additional uses as livestock feeds, baking and brewing industries while (Bhavana, 2022) noted however that several reasons including continuous cropping, increased population pressure on arable land, degradation of land as natural resources, inappropriate production techniques, episodes of bad weather and the need to evaluate and increase investment in soil fertility have led to decline in productivity of maize.

Thus, it is against this backdrop, that the need to evaluate and validate the pedochemical and fertility status of the soils influencing the production of local maize crop in the Cross River agroecology of Nigeria becomes increasingly indispensible. The primary purpose of soil evaluation is to assess the adequacy, excess or deficiency of available nutrients for crop growth and to monitor changes arising from farming practices (Dhived *et al.*, 2022; Nisha and Komal, 2022; Caberry *et al.*, 1989). This information is needed for optimum crop production, to avoid the transmittance of undesirable levels of some nutrients into the environment and to guarantee a suitable nutrient content in crop products. Although soil analysis may not be a perfect tool, it is the most effective and practical avenue of assessing the nutrient carrying capacity of soils. The validation will bridge the knowledge gap and unveil the baseline fertility data in the study area through which subsequent or rather future soils status can be judged for decision on best management practices to improve soil productivity on a sustainable basis.

MATERIALS AND METHODS

Study area

Cross River is a state in Southern Nigeria bordering Cameroon to the east. Its capital is Calabar. Cross River State has a total of 18 Local Government Areas (Fig 1).

Source of experimental materials

The maize plants was collected from the 18 Local Governments in Cross River State and transported to the planting site in Calabar, Nigeria shown in Table 1.

Experimental site

The experiment was conducted in March 2020 to July, 2022 in Calabar, Southern Nigeria, which lies between latitude 05°32′ and 04°46′N and longitude 08°19′ and 09°28′E. The area is of humid tropical climate, characterized by high rainfall with two main seasons, dry and rainy seasons. The vegetation is tropical rain forest of the humid agro-ecological zone in Nigeria. According to USDA system of classification (Soil Survey), (Ubi and Ubi, 2004), Calabar soils are typic Paleudult. The soil is acid sands derived from coastal plain sands consisting of sand deposits which lie across Cross River and underlain by massive deposits of limestone, Quartz, Fe and Al oxides dominate the soil with kaolinite as clay mineral (Ubi *et al.*, 2016).

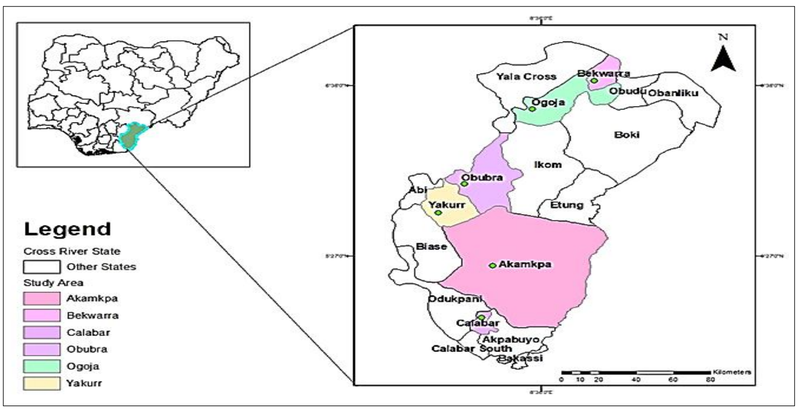

Fig 1: Map of cross river state showing 18 local government areas of study area.

The research was carried out in a field behind Biological Sciences Faculty building University of Calabar in collaboration with Biggmade Scientific Research Academy laboratory, Calabar south, Cross River State, Nigeria.

Land preparing and planting

A piece of land located behind Biological Sciences Faculty building, University of Calabar was cleared, before the maize was cultivated on plastic buckets containing 2 kg of the bulk soils collected from the different LGAs which was spaced 1 m apart. Three seeds were sown per hole and the spacing between the plants was 20 cm for proper growth and yield. The local maize obtained from each of the local government area or study area was planted on separate ridges and each replicated thrice.

Data collection

Maize crop data was collected at the flowering stage of the plants for the following morphological parameters number of tassels, number of cobs per stand, size of cobs, days to tasseling, days to silking, days to maturity, ear diameter (cm), ear length (cm), rows per ear (no.), kernels per row (no.) and 100 seed weight (g).

Data analysis

Data collected for morphological parameters was subjected to analysis of variance tests (ANOVA) in other to determine the level of significance among the means. Significant differences among the group means were determined using the least significant difference (LSD) at the level of 5% probability. The experiment was carried out in a simple complete randomize design (CRD) and same local maize accession was obtained from each of the Local Government Area.

Collection of soil samples for pedochemical and fertility evaluation

Random sampling technique was used to get soil samples in the selected local government areas as shown in Table 1. Each sampling site was further demarcated based on physical characteristics such as vegetation, drainage, slope, soil colour and texture. A total of 54 soil samples were collected from cultivated and uncultivated farm lands at 3 sites per LGA at a depth of 0-20 cm. Each of the soil collected from 1 LGA was bulked to give a total of 18 soil samples each representing an LGA. Each LGA bulked soil was divided into two parts. One part used for the cultivation of the local maize while the other part was taken to the laboratory for pedochemical and nutrient status analysis.

Laboratory analysis of soil samples

Preparation of soil samples

The soil samples were air-dried, crushed and sieved through a 2 mm sieve. The less than 2 mm portion (fine earth separates), were used to carry out the laboratory analysis. Each of the collected soil samples were divided into two portions. One portion of about 50g were used for laboratory analysis while the other portions were bulked and used for planting the maize test crop.

Soil pH (Acidity)

Soil pH was determined both in water and in 1 MKC1 solutions in a 1:2.0 soil to solution ratio using a Pye Unicam model 290 MK pH meter.

Exchangeable bases

The exchangeable bases were extracted with neutral (pH 7.0) ammonium acetate (NH_4OAc) solution by repeated

Table 1: Sampling location and agroecology of the different local government areas of cross river state and global position system (GPS) coordinates where soil samples were taken using soil augur.

Local government area	Agroecology	GPS coordinates
Abi local government	Rain forest	5°56′30.2″N 8°09′39.3″E
Akamkpa local government	Rain forest	5°19′13.5″N 8°20′57.4″E
Akpabuyo local government	Rain forest	4°55′26.2″N 8°24′28.3″E
Bekwarra local government	Derived savannah	6°36′35.2″N 8°51′49.4″E
Bakassi local government	Rain forest	4°53′37.8″N 8°33′19.8″E
Biase local government	Rain forest	5°25′05.9″N 8°12′33.3″E
Boki local government	Rain forest	6°24′18.1″N 8°48′05.0″E
Calabar municipal local government	Rain forest	4°59′51.7″N 8°20′19.4″E
Calabar south local government	Rain forest	4°46′01.7″N 8°19′35.5″E
Etung local government	Rain forest	5°48′08.8″N 8°50′16.9″E
Ikom local government	Rain forest	6°03′02.5″N 8°41′14.2″E
Obanliku local government	Rain forest	6°32′44.0″N 9°13′18.2″E
Obubra local government	Rain forest	5°55′02.5″N 8°14′14.5″E
Obudu local government	Rain forest	6°17′14.5″N 8°54′55.0″E
Odukpani local government	Rain forest	5°16′33.3″N 8°05′19.4″E
Ogoja local government	Derived savannah	6°39′32.9″N 8°47′54.2″E
Yakurr local government	Rain forest	5°48′36.5″N 8°04′42.0″E
Yala local government	Derived savannah	6°40′08.5″N 8°35′22.8″E

extraction. Potassium and sodium were read from the undiluted extract on a Gallenkamp flame photometer, while calcium and magnesium in solution were read on a Pye Unicam Model Sp 192 atomic absorption spectrophotometer (AAS) at 423 and 285 m wave length respectively. Boron and Zinc were also determined using AAS.

Determination of cation exchange capacity (CEC)

CEC was determined by the neutral (pH 7.0) NH_40Ac saturation method (Anderson and Ingram, 1993). The cation exchange capacity of the clay fraction was calculated using the method as follows:

$$\text{CEC (clay)} = \text{CEC } (NH_4OAc) - (3.5 \times \%\ OC \times 100)$$

Determination of organic carbon (OC)

The acid-dichromate wet oxidation method of Walkey and Black as described (Black, 1965) was used in the determination of organic carbon. The heat of dilution of added concentrated sulphuric acid (H_2SO_4) hastened the reaction.

Table 2: Ratings for soil fertility classes in Nigeria (FAO, 1996).

Parameters	Classification		
	Low	Medium	High
Carbon (% C)	<1.0	1-2	>2
Nitrogen (Total N %)	<0.10	0.10-0.15	>0.15
Phosphorus			
Bray-1 (ppm P)	<10	10-20	>20
Bray-11 (ppm P)	<15	15-25	>25
Exch. Potassium	<0.15	0.15-0.25	>0.25

Determination of available phosphorus

Available phosphorus was extracted by the Bray No.1 method. Phosphorus in solution was determined calorimetrically by the ascorbic acid method (Bray and Kurtz, 1945).

Determination of total nitrogen

Total nitrogen was determined by the micro-Kjeldahl technique. Potassium sulphate (K_2SO_4) was used as the catalyst.

Soil chemical and fertility data interpretation criteria

The interpretation of the chemical and fertility analytical data were based on the guidelines and critical limits established by experimentation and research findings (Table 2) by various researchers and outlined in Table 2.

RESULTS AND DISCUSSION

The results of soil analysis for pedochemical and fertility indices of the soils influencing maize crop production in the Cross River agro-ecology of Nigeria is presented in Table 3 and Fig 2 to 5. The results reveal that organic carbon (Fig 2) ranged from 1.40 g/kg^3 in Obanliku soil to 2.84 g/kg^3 in Ikom LGA soil. Available phosphorus (Fig 3) varied 3.31 mg/kg in Obanliku soil to 29.24 mg/kg in Odukpani LGA soil. The amount of Calcium in the agroecology ranged from 0.67 Cmol/kg^3 in Akpabuyo soil to 5.00 cmol/kg^3 in Obudu soil. Similarly, the volume of Magnesium was found to vary from 1.01 Cmol/kg^3 in Obudu soil to 2.48 Cmol/kg^3 in Akamkpa soil while Potassium varied between 0.31 Cmol/kg^3 in Etung soil to 0.60 Cmol/kg^3 in Calabar South soil. The value of total nitrogen (Fig 4) in the cross river agroecology varied from 0.11 g/kg^3 in Bekwarra soil to 0.24 g/kg^3 in Akamkpa

Table 3: Identification of pedochemical characteristics of soils influencing local maize production in the cross river agro-ecology of Nigeria.

	O.C	Phosphoru	Calcium	Magnesium	Potassium	Total N	CEC	Acidity	Boron	Zinc
Abi	2.19	16.83	2.87	2.04	0.36	0.18	7.01	5.94	0.7	2.42
Akamkpa	2.83	24.21	0.67	2.48	0.42	0.24	11.44	5.07	0.52	3.74
Akpabuyo	2.72	22.11	0.96	2.33	0.46	0.21	10.89	5.02	1.21	4.01
Bakassi	2.69	26.32	1.13	2.11	0.52	0.22	10.93	5.11	0.83	3.92
Bekwarra	1.59	5.42	3.04	1.69	0.5	0.11	9.98	5.88	1.42	3.05
Biase	2.11	17.28	2.09	1.77	0.53	0.2	11.93	5.62	1.5	4.24
Boki	2.77	16.44	4.11	1.65	0.39	0.18	7.89	5.68	1.92	5.00
Cal. Mun.	2.73	23.12	1.63	2.02	0.59	0.2	11.32	5.00	0.96	2.13
Cal. South	2.7	23.61	1.89	1.98	0.6	0.21	12.01	5.02	1.12	1.96
Etung	2.83	17.89	4.51	1.25	0.31	0.2	9.35	5.91	2.01	3.44
Ikom	2.84	19.62	3.77	1.67	0.37	0.2	10.01	5.83	1.85	4.52
Obanliku	1.4	3.31	4.21	1.33	0.48	0.12	9.11	5.72	1.73	3.21
Obubra	2.52	9.09	5.00	1.01	0.36	0.18	8.31	5.62	0.54	4.31
Obudu	1.52	4.09	4.72	1.04	0.45	0.14	8.03	5.79	0.99	2.42
Odukpani	2.66	29.24	1.44	2.2	0.55	0.22	10.2	5.1	1.37	1.93
Ogoja	1.92	6.24	4.61	1.23	0.53	0.15	7.59	6.01	1.74	2.69
Yakurr	2.49	18.31	4.43	1.27	0.38	0.19	9.01	5.74	0.83	3.62
Yala	1.67	7.01	4.96	1.06	0.52	0.13	8.82	6.00	1.46	3.71

Units of determination; Organic carbon (g/kg^3); Phosphorus (mg/kg); Calcium (Cmol/kg^3); Magnesium (Cmol/kg^3); Potassium (Cmol/kg^3); Total nitrogen (g/kg^3); CEC (Cmol/kg^3); Zinc (mg/kg^3); Boron (mg/kg^3).

LGA soil. Cation exchange capacity (CEC) in the agroecology also varied from 7.01 Cmol/kg^3 in Abi soil to 12.01 Cmol/kg^3 in Calabar South soil. Soils in the agroecology were more acidic 5.00 in Calabar Municipality soil to less acidic 0.61 in Ogoja LGA soil. Micro nutrients status was reported for Boron and Zinc contents in the agroecology among other micro nutrients analysed. Boron varied from 0.52 mg/kg^3 in Akamkpa soil to 2.01 mg/kg^3 in Etung soil while Zinc also ranged from 1.93 mg/kg^3 in Odukpani soil to 5.0 mg/kg^3 in Boki soil of the Cross River agroecology of Nigeria. The result of fertility indices of the soils in the cross river agroecology is presented in Table 4. Based on

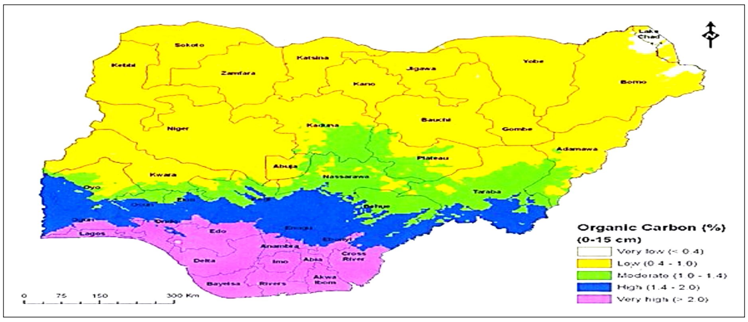

Fig 2: Organic carbon for cross river agroecology ranged from high to very high >2.0.

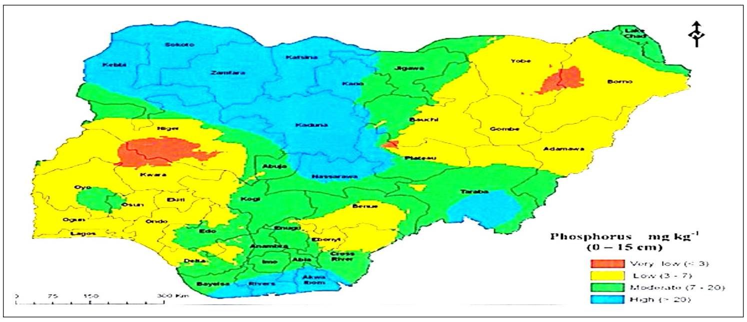

Fig 3: Phosphorus for cross river agroecology is moderate and range from 7-20.

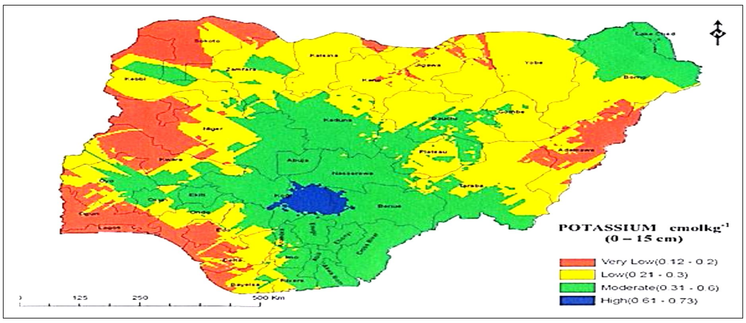

Fig 4: Potassium for cross river agroecology is moderate and range from >0.31-0.60.

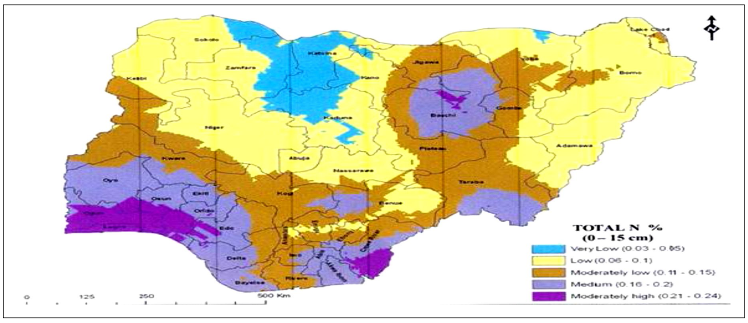

Fig 5: Total nitrogen for cross river agroecology is ranged from moderately low (0.11 -0.15) to medium (0.16-0.20) to moderately high (0.21-0.24).

the fertility ratings indices used as shown in (Table 2). Potassium nutrient was rated high throughout the cross river agroecology. The results also show that 33.33% of the soils in the agroecology was rated high, medium and low for available phosphorus fertility nutrient while the remaining soils has medium and low ratings of 33.33% each for available phosphorus nutrient (Table 4). Total nitrogen nutrient fertility ratings for the agroecology soils showed 77.78% high fertility ratings and 22.22% medium fertility ratings. Results of organic carbon nutrient fertility rating of the soils (Table 4) shows that organic carbon content of the soils in the agroecology had a high fertility rating of 72.23% while 27.67% of the soils in the agroecology had medium rating for organic carbon content.

In summary the fertility status of the soils of cross river agroecology can be rated as High in potassium, organic carbon, total nitrogen and available phosphorus. Medium in organic carbon, total nitrogen and available phosphorus and only low in available phosphorus in some areas (Table 4). With good management options such as good conservation practices, adequate control of pests and diseases and proper use of organic and inorganic fertilizer, it can increase and positively influence the sustainable production of maize in the cross river agroecology.

Principal component analysis of pedochemical and fertility indices supporting local maize production in cross river agro-ecology of Nigeria

Ten (10) principal components (PC) contributed the total 100% to support maize crop production in the agroecology and were used to explain the variations in the Eigen values and percentage contributions from pedochemical and fertility indices enhancing maize crop production in the Cross river agroecology. The major contribution to support maize productivity in the agroecology was from PC1 with a high Eigen value of 70.876 and the highest percentage contribution of 94.992% out of 100% (Table 5). The principal contributing pedochemical and fertility indices to the PC1 is phosphorus with a major loading value of 0.979 (Table 6) while Zinc (-0.005) was the least loading or releasing nutrient in PC1 towards the maize crop productivity.

Table 5 and 6 revealed that PC2 had an Eigen value of 2.0315 and contributed only 2.7227% to the total 100% enhancement of maize production in the agroecology. Calcium was the major contributing element with a loading value of 0.560 to PC2 and CEC was the least released nutrients (-0.773) in this component. Total nitrogen was the most released nutrient that contributed 0.995 loading value (Table 6) towards growth and yield of maize in PC10 which showed an Eigen value of 0.00008 with the least percentage contribution of 0.00001% to the total 100% (Table 5). Also in PC10, soil acidity index had the least loading value of -0.006 to the component towards the enhancement of maize production in the agroecology.

Table 7 presents result of the percentage contribution of the bulked soil from the different LGAs used for the cultivation of the test (maize) crop revealed the contribution of the different Cross River agroecology towards maize productivity in the area. For PC1, soils in Bakassi agroecology of Cross River contributed the highest pedochemical and fertility inputs to maize productivity with a loading value of 13.222 while soils in Obanliku showed

Table 4: Identification of fertility indices of soils influencing local maize production in the Cross River agro-ecology of Nigeria.

LGA	Org. carbon	Fertility ratings	Total nitrogen	Fertility ratings	Available P	Fertility ratings	Potassium	Fertility ratings
ABI	2.19	High	0.18	High	16.83	Medium	0.36	High
Akamkpa	2.83	High	0.24	High	24.21	High	0.42	High
Akpabuyo	2.72	High	0.21	High	22.11	High	0.46	High
Bakassi	2.69	High	0.22	High	26.32	High	0.52	High
Bekwarra	1.59	Medium	0.11	Medium	5.42	Low	0.5	High
Biase	2.11	High	0.2	High	17.28	Medium	0.53	High
Boki	2.77	High	0.18	High	16.44	Medium	0.39	High
Calabar Mun.	2.73	High	0.2	High	23.12	High	0.59	High
Calabar South	2.7	High	0.21	High	23.61	High	0.6	High
Etung	2.83	High	0.2	High	17.89	Medium	0.31	High
Ikom	2.84	High	0.2	High	19.62	Medium	0.37	High
Obanliku	1.4	Medium	0.12	Medium	3.31	Low	0.48	High
Obubra	2.52	High	0.18	High	9.09	Low	0.36	High
Obudu	1.52	Medium	0.14	Medium	4.09	Low	0.14	Low
Odukpani	2.66	High	0.22	High	29.24	High	0.55	High
Ogoja	1.92	Medium	0.15	High	6.24	Low	0.53	High
Yakurr	2.49	High	0.19	High	18.31	Medium	0.38	High
Yala	1.67	Medium	0.13	Medium	7.01	Low	0.52	High

Units of determination; Organic carbon (g/kg^3); Phosphorus (mg/kg); Potassium (cmol/kg^3); Total nitrogen (g/kg^3).

Table 5: Eigen values and percentage contribution of principal component to soil fertility in the study area.

Principal component	Eigenvalue	Contribution (%)
PC1	70.876	94.992
PC2	2.0315	2.7227
PC3	0.95846	1.2846
PC4	0.48628	0.6517
PC5	0.18532	0.2483
PC6	0.04431	0.0593
PC7	0.02338	0.0313
PC8	0.00518	0.0069
PC9	0.00186	0.0025
PC10	0.00008	0.0001
Total		100.00

the least loading value of -12.84 in PC1 towards maize productivity in the Cross River agroecology. For PC2, soils in Boki agroecology had the major contributing or loading value with 2.281 to maize productivity in PC2 while soil in Bekwarra with small loading value of -2.270 was the least contributor to maize production in PC2. The soils in Akamkpa contributed the most of pedochemical and fertility inputs to the production of maize with loading value of 0.014 in PC10 while soils in Bakassi and Calabar Municipality had the least inputs of pedochemical and fertility towards maize productivity in PC10 with a loading value of -0.009.

The dendrogram in Fig 6 delineated and categorized the 18 LGAs in the Cross River agroecology in terms of relationship in pedochemical and fertility indices into 2 major clusters. This shows that all soils in the Cross River agroecology have the same parent material. Cluster 1 has

Table 6: Loading values showing percentage contribution of pedochemical indices to soil fertility enhancing maize production in the cross river agroecology.

	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
Org. Carbon	0.051	0.102	0.134	0.021	-0.104	0.801	0.494	-0.237	0.115	-0.030
Phosphorus	0.979	0.178	-0.002	0.053	0.001	-0.065	-0.029	0.008	-0.003	-0.002
Calcium	-0.143	0.560	0.244	0.659	-0.195	-0.037	-0.014	0.357	0.042	0.021
Magnesium	0.044	-0.114	-0.081	-0.273	0.178	0.098	0.314	0.860	0.140	0.055
Potassium	0.002	-0.039	-0.028	0.027	0.027	-0.015	-0.217	-0.085	0.967	0.066
Total nitrogen	0.004	0.002	0.005	-0.002	-0.013	0.016	0.017	-0.058	-0.068	0.995
CE capacity	0.115	-0.773	0.364	0.475	-0.114	-0.038	0.099	0.069	-0.003	0.002
Acidity	-0.034	0.113	0.041	0.038	0.176	-0.553	0.754	-0.238	0.139	-0.006
Boron	-0.013	0.041	0.154	0.225	0.933	0.160	-0.135	-0.061	-0.059	0.004
Zinc	-0.005	0.126	0.869	-0.454	-0.037	-0.091	-0.103	0.007	0.021	-0.001

Table 7: Loading values showing percentage contribution of agro-ecology to soil fertility for maize production in the study area.

	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
Abi	0.435	1.885	-1.954	-1.176	0.008	-0.237	0.241	0.031	-0.002	0.001
Akamkpa	8.569	-1.386	0.244	-0.903	-0.416	0.081	0.172	0.062	-0.023	0.014
Akpabuyo	6.385	-1.110	0.453	-1.016	0.198	0.238	-0.095	-0.023	-0.039	-0.003
Bakassi	10.48	-0.293	0.381	-0.639	-0.204	-0.194	-0.185	-0.110	0.013	-0.009
Bekwarra	-10.486	-2.270	-0.209	-0.302	0.264	-0.037	0.220	0.011	0.010	-0.022
Biase	1.527	-2.032	1.348	0.091	0.186	-0.379	0.028	-0.088	0.009	0.013
Boki	-0.033	2.281	1.199	-0.749	0.530	0.237	-0.148	0.063	0.036	-0.002
Cal. Mun.	7.330	-1.107	-0.878	0.571	-0.199	0.248	0.001	-0.019	0.041	-0.009
Cal. South	7.847	-1.419	-0.687	1.222	-0.173	0.182	0.032	0.081	0.038	0.005
Etung	1.483	1.522	0.537	1.134	0.390	0.112	0.192	-0.104	-0.089	-0.004
Ikom	3.378	0.976	1.471	0.409	0.333	-0.029	0.191	0.082	0.011	0.002
Obanliku	-12.84	-1.28	-0.052	0.026	0.341	0.026	-0.203	0.108	-0.060	0.004
Obubra	-7.331	1.045	0.786	-0.186	-1.063	0.281	-0.009	-0.046	0.005	0.001
Obudu	-12.27	-0.095	-1.081	0.167	-0.348	-0.019	-0.130	-0.032	-0.057	0.006
Odukpani	13.222	0.718	-1.473	0.376	0.419	-0.110	-0.215	0.009	-0.017	0.001
Ogoja	-10.19	0.671	-0.876	0.014	0.448	0.172	0.041	-0.119	0.074	0.013
Yakurr	1.871	1.730	0.311	0.577	-0.651	-0.282	-0.016	0.053	-0.010	-0.005
Yala	-9.368	0.164	0.479	0.385	-0.064	-0.287	-0.114	0.040	0.059	-0.003

2 major sub cluster groups C1 and C2. Each of the three subgroups contains six LGAs as depicted in the dendrogram. Group 1 (C1) consist of Biase, Boki, Etung, Ogoja, Ikom and Abi LGAs. Group 2 (C2) consist of Odukpani, Akamkpa, Bakassi, Akpabuyo, Calabar Municipality and Calabar South LGAs and group 3 (C3) consist of Bekwarra, Obanliku, Obudu, Obubra, Ogoja and Yala LGAs.

Yield performance of local maize (*Zea mays* L) grown in the different soils of the cross river agroecology

Table 8 present results on the yield performance of local maize genotypes collected from across all eighteen local government areas of Cross River State and grown on same soil here in Calabar. The results indicates that significant ($p<0.05$) differences were observed from yield components like size of cobs, kernels per row, days to maturity and 100 seed weight per plant among the evaluated maize. Maize cob sizes ranged from 10.00±1.15 cm in Yala soil to 14.77±0.39 cm of maize planted in Akpabuyo soil (Table 8). Days to maturity ranged from 84.67±3.84 days in maize planted in Akamkpa soil to 94±1.53 days in maize planted in Odukpani soil. The weight of a 100 seed per treatment varied ($p<0.05$) significantly among the local maize and range from 14.59±1.56 g in maize planted in Calabar municipality soil to 28.54±0.52 g obtained from maize planted in Obudu soil. The number of kernels per row also differed ($P<0.05$) significantly among the local maize. Maize planted in Akamkpa soil had the least kernels number per row of cob of 10.67±1.20 while maize planted in Obanliku soil had the highest number of kernels per row of cob measuring 15.00±0.58 (Table 8).

The number of tassels per plant, days to tasseling, +number of cobs per plant and days to silking did not show any significant ($p>0.05$) differences among the local maize evaluated. However, average number of tassels numbering 9.00±1.15 was counted from the maize planted in Odukpani soil while the highest numbers of tassels per plant of 14.33±2.18 were counted from the maize planted in Boki and Akpabuyo soils respectively (Table 8). Average days to tasseling among the maize ranges from 55.67±1.33 days in maize planted in Calabar Municipality soil to 62.69±2.60 days in maize planted in Calabar South soil. Similarly, average number of cobs per plant varied from 1.00±0.00 across 94% of all evaluated to 1.33±0.33 obtained from Yakurr soil. Average number of days to silking evaluated among the maize ecotype did not show any significant ($p>0.05$) differences among the ecotypes. The least number of days to silk development in maize was recorded from Akamkpa soil (63.67±1.20 days) while the highest number of days to silk development was counted from maize planted in Yakurr soil (68±0.58 days).

The high acidity values for the study area could be attributed to the present of high sulphate derivable from domestic waste and the acidity is suggested to be proportional to the amount of sulphate present in the water. Maize plants do not tolerate acidity below pH 3.0 critical level (Ubi *et al.*, 2016; Adu, 1992). In general, it may be suggested that irrigation water below a pH of 3.5 may be unsuitable for rice growth in the state as yields of maize could be reduced due to sulphur accumulation (Gweshengwe *et al.*, 2020; Binswanger and Pringal, 1988).

Calcium and Magnesium (Ca, Mg) are cations (positively charged ions) which are present in soil. In most cases the sum of Ca and Mg are reported in milliequivalents/liter. Together Ca + Mg may be used to establish the relationship to total salinity and to estimate the sodium hazard. Cation exchange capacity is low in some places with attendant implication on nutrition and holding capacity. Acidity indicator showed high degree of acidic soils within the state which is inimical to maize crop production. Liming option can be used to properly address this (Bonhemme *et al.*, 1994).

Fertility ranking of nutrients in terms of their values in the bulk soils on the average showed that potassium was all high, organic carbon was high to medium, total nitrogen was high to medium while available phosphorus was high, medium and low (Fig 7). Ranking the nutrients in terms of the percentages in the soil samples gave a similar trend with maize, indicating that the uptake of nitrogen was significantly higher than values of either P, K, Ca, Mg, B or Zn under similar experimental condition (Beltrab *et al.*, 1996).

These findings in the present study may be attributed to the fact that no treatment was applied in the cause of the research on the local maize. Hence, the contrast with the reports of (Agbachom *et al.*, 2022, Christo and Onuh, 2005), all of whom have reported that yield attributes of maize varied ($p<0.05$) significantly among maize varieties placed on different fertilizer trials. This present result is contrary to the

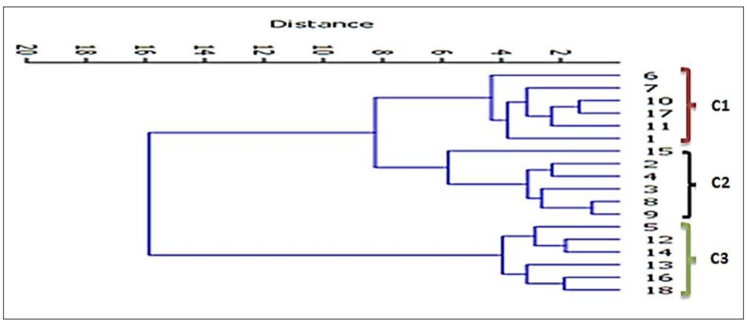

Fig 6: Dendrogram showing pedochemical and nutrient status cluster relationship among LGAs agroecology in the study area.

Table 8: Yield performance of local maize (*Zea mays*) grown in different soils of the cross river agroecology.

LGA	No. of tassels	Days to tasseling	No. of cobs/plant	Days to silking	Size of cobs (cm)	100 seeds weight (g)	Kernels per row	Days to maturity
ABI	13.33±1.20	61.33±3.18	1.33±0.00	65.33±3.17	13.17b±1.87	24.24b±3.45	13.00b±0.57	88.33c±0.88
Akamkpa	12.00±0.57	60.00±1.73	1.00±0.00	65.00±1.15	13.00b±0.57	19.43d±0.43	10.67e±0.33	84.67d±3.84
Akpabuyo	14.33±2.18	59.33±0.88	1.00±0.00	63.67±1.20	14.77a±0.39	21.69d±1.63	12.67c±1.45	91.00b±1.73
Bakassi	12.00±0.57	58.67±2.73	1.33±0.33	63.67±2.33	13.69a±0.67	19.64d±3.70	11.33d±0.88	89.33c±2.33
Bekwarra	10.67±1.45	60.33±2.60	1.00±0.00	65.00±2.31	13.20b±1.25	19.96d±0.71	12.00c±0.58	94.00a±2.52
Biase	10.67±1.20	60.33±1.87	1.00±0.00	64.00±3.06	12.87c±0.74	20.63d±1.03	11.00d±0.58	89.67c±1.76
Boki	14.33±0.88	58.33±1.76	1.30±0.33	64.00±2.08	14.27a±0.87	21.57d±1.54	12.00c±0.58	95.33a±2.33
Cal. Mun.	13.33±0.88	55.67±1.33	1.00±0.00	60.67±1.45	12.50c±0.87	14.59e±0.89	11.00d±1.15	92.67b±2.03
Cal. South	11.33±1.45	62.69±2.60	1.00±0.00	67.00±2.65	14.10a±0.59	22.15c±3.76	12.00±0.58	93.33a±1.20
Etung	10.67±1.45	58.00±1.15	1.00±0.00	65.33±0.67	10.00d±1.15	25.85b±3.31	11.67d±0.67	89.33c±1.20
Ikom	11.33±1.20	59.00±1.53	1.67±0.33	65.67±1.33	10.43d±0.47	20.96c±1.40	12.33c±0.33	91.00b±2.65
Obanliku	10.00±1.00	61.67±1.20	1.00±0.00	68.00±0.58	13.00c±0.58	14.65e±1.04	15.00a±0.58	93.00a±1.73
Obubra	10.30±1.20	61.33±1.86	1.00±0.00	67.67±1.76	14.70a±0.46	17.28b±2.16	13.00b±0.58	90.67b±3.18
Obudu	11.67±1.20	58.00±1.73	1.00±0.00	64.00±1.73	13.07±1.05	28.54a±0.52	13.67b±0.88	91.00b±3.61
Odukpani	9.00±1.15	59.33±1.45	1.30±0.33	64.33±1.45	11.27d±0.93	23.31c±1.42	11.67d±0.88	94.00a±1.53
Ogoja	13.00±0.58	58.00±2.08	1.00±0.00	64.33±1.86	12.83c±0.64	19.87b±3.63	13.33b±1.20	88.33c±1.20
Yakurr	10.00±0.58	59.00±1.15	1.67±0.33	66.00±0.58	12.67c±1.45	21.31c±4.76	10.67e±1.20	92.67b±2.40
Yala	13.33±0.88	60.33±1.20	1.00±0.00	66.33±1.20	10.00e±1.15	20.23c±4.40	12.00c±0.58	91.00b±2.31
LSD (0.05)	NS	NS	NS	NS	1.22	2.25	0.96	3.03

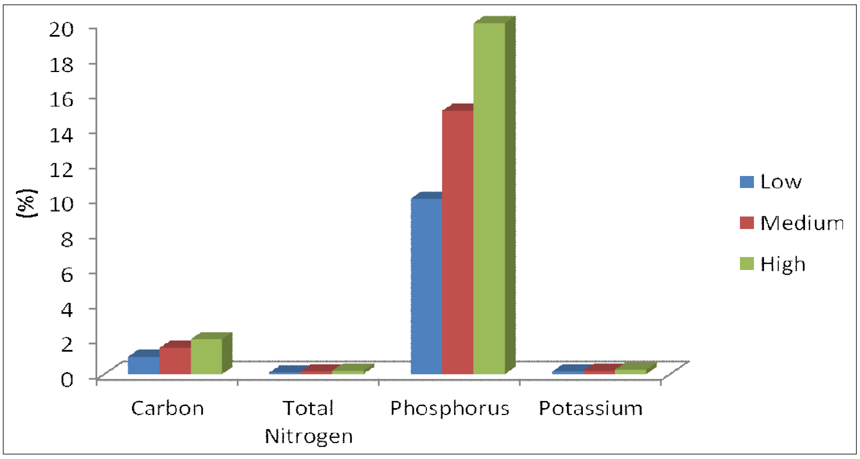

Fig 7: Ratings for soil fertility classes in Nigeria (FAO, 1996).

reports because of the non-application of fertilizer treatments to the test crops as reported by (Eze and Obi, 2008; Eshiet, 1985). It was also gathered from the present study that days to tasseling, number of tassels per plant, number of cobs per plant and days to silking did not differ ($p<0.05$) significantly among the evaluated maize ecotypes. This also agrees with the reports and findings by (Ubi *et al.*, 2016), who in their various works reported that the days to tasseling, number of tassels per plant, number of cobs per plant and days to silking did not differ ($p<0.05$) significantly among the evaluated maize ecotypes treated with different organic fertilizers (Kalu *et al.*, 2022). The evaluation provides the baseline fertility data through which subsequent and future soils can be evaluated for decision on best management practices to improve soil productivity on a sustainable basis and intensification of agriculture through an integrated approach that involves land and nutrient management to enhance food security and farm income.

CONCLUSION

The study thus identified and validated the prevailing characteristics of soils in the Cross River agroecology influencing the production profile of the staple maize food crop in the state. From the present study, it was concluded that the soils that support maize production in the Cross River agroecology shows high to medium concentration of organic carbon, available phosphorus, calcium, potassium and total nitrogen. Cation exchange capacity (CEC) was medium. Soils were more acidic to less acidic. Boron and zinc were identified to vary slightly in the Cross River agroecology of Nigeria.

Ten (10) principal components (PC) contributed the total 100% to support maize crop production in the agroecology and were used to explain the variations in the Eigen values and percentage contributions from pedochemical and fertility indices supporting maize crop production in the Cross river agroecology. Phosphorus pedochemical and the soils in Bakassi had the most loading values in PC1. The scatter plots revealed the distribution of the pedochemicals and LGAs into two major component axes. The dendrogram delineated and categorized the 18 LGAs in the Cross River agroecology in terms of relationship in pedochemical and fertility indices into 2 major clusters of 3 groups. This shows that all soils in the Cross River agroecology have the same parent material.

Significant ($p<0.05$) differences were detected in some yield components such as size of cobs, days to maturity, kernels per row and a 100 seed weight. Others such as number of tassel per plant, days to silking, days to tasseling and number of cobs per plant did not vary among the different localities. Thus, the study concluded that maize production in the Cross River agroecology can be sustainably increased through adequate soil improvement practices such as fertilization, mulching, liming, crop rotation, organic manure application and pest and disease management to ensure food security and sustainability. The validation provides the baseline fertility data through which subsequent or rather future soil can be judged, managed and evaluated for decision on best management practices to improve soil productivity on a sustainable basis.

Conflict of interest: None.

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