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Analysis of soils from cassava farms in floodplain terrain

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The study was carried out to analyze soils from cassava farms in floodplain terrain of the River Benue. Cassava is the most extensively cultivated crop in Benue State. Soil samples were collected randomly from cassava farms owned by members of farming cooperative societies in Makurdi, Tarka, and Gboko Local Government Areas. These samples were analysed for physical and chemical properties. The pH was slightly acidic with a mean of 5.7 for surface soils and 5.7 for subsurface soils. The organic carbon content had a mean of 0.7% for surface soils and a mean of 0.72% for subsurface soils. The total percentage nitrogen had a mean of 0.05% for surface soils and 0.05% for subsurface soils. Available phosphorus had a mean of 8.48 mg kg^{-1} for surface soils, while subsurface soils had a mean of 5.66 mg kg^{-1}. The base saturation percentage was 86.58% for surface soils and a mean value of 86.55% for subsurface soils. The values of micro-nutrients were all below tolerable limits. The study recommends the effective application of inorganic fertilizers such as NPK to optimize crop production. Governments should support farmers with credit facilities, agricultural laboratory services, and effective extension services.

Key words: Soil assessment, soil nutrients, organic carbon, phosphorus, nitrogen, micro-nutrients, River Benue, Nigeria.

INTRODUCTION

Cassava is an important source of calories for millions of people in Latin America, Asia, and Africa. Cassava has become very significant globally for agricultural income and food security. It is however associated mostly with peasant farmers, often women, ploughing marginal lands (FAO, 2008). According to the Food and Agriculture Organisation (2008), the Global Cassava Development Strategy launched in 2000 promoted cassava "as a raw material base for an array of processed products that will effectively increase demand for cassava and contribute to agricultural transformation and economic growth in developing countries."

The earliest sites of cassava cultivation were in Northern Brazil and Central America. It was from these locations that cassava found its way to various tropical and subtropical areas in the world and became a major

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Table 1. Major crops and area cultivated in Benue State (2009-2012) (Benue State Ministry of Agriculture, 2013).

Crop	Area cultivated ('000 Hectares)			
	2009	2010	2011	2012
Maize	108.99	114.98	104.15	123.65
Millet	43.03	42.68	42.60	46.80
Sorghum	112.26	113.44	110.17	130.47
Rice	144.42	155.48	137.49	182.90
Cassava	276.03	281.50	267.63	294.65
Yam	226.76	228.14	225.97	289.49
Ginger	1.24	1.30	0.63	0.75
Melon	37.63	89.10	29.16	31.60
Tomatoes	13.35	16.30	6.93	7.95
Sesame seed	46.55	45.38	41.28	41.28
Groundnut	206.38	207.46	199.04	201.04
Soybeans	90.84	93.62	86.13	100.13
Citrus	101.25	152.12	69.52	70.57
Mangoes	97.94	106.38	35.10	45.10

staple food (Eke-Okoro and Njoku, 2012). The global output of cassava produce surpassed 230 million metric tons in 2010. Most of the global cassava produce is in Africa with Nigeria being the largest producer. Nigeria produced 107 million metric tons of cassava in 2012 and 2013 (FAO, 2015). Portuguese traders were said to have introduced cassava to Warri in Western Nigeria in the late 18 Century. Since that time, cassava has become a daily food necessity of staple significance to over 70% of Nigerians (Eke-Okoro and Njoku, 2012).

Tropical conditions are suitable for cassava cultivation. Suitable parameters for cassava cultivation in savannah regions are documented in Titus et al. (2011) and Ande (2011). Cassava can grow on a wide variety of soils within a temperature of between 25 and 29°C, and with a rainfall range of 500 to 1500 mm. Cassava can grow on level to moderate slope and does not require much water for growth.

Benue State in Nigeria is known for the production of a varied number of agricultural produce such as grains crops, roots and tuber crops, legumes, fruits and livestock. The most extensively cultivated crop in Benue State between 2009 and 2012 was cassava (Benue State, 2013). According to an agricultural investment document on Benue State (Benue State, 2013), an expanse of 276, 030 hectares of cultivated cassava produced 3, 643, 660 metric tons in 2009 and 294, 650 hectares produced 3, 597, 280 metric tons in 2012. Other crops such as yams, groundnut, rice and maize were also extensively cultivated during the same period (Tables 1 and 2).

Most parts of Benue State are located either in the lowland or upland areas of the floodplain of the River Benue. The floodplain of the River Benue is about 181,000 hectares making it an important economic resource to Nigeria (Ita et al., 1985).

Floodplain soils are of immense interest to the global community because of the fragile ecosystem and high agricultural potential (Nsor and Akamigbo, 2009). Floodplains ecosystems are fragile; using them for crop cultivation has resulted in adverse environmental and ecological issues. Babalola et al. (2011) decried the gross misuse of floodplains in Nigeria stating that this has negatively influenced the natural hydrological cycles. According to Babalola et al. (2011), inefficient cultivation methods have resulted in low yields making many crop farmers to abandon floodplains due to depleted fertility and erosion.

The trend of cassava cultivation in Benue State is not surprising because the Federal Government of Nigeria in the last few years has called for increased cultivation of cassava. Cassava is also a staple food in North Central Nigeria. However, low yields of crops cultivated in Benue have been observed through the reduction in supply chain to some processing plants in Benue (Shabu et al., 2011). The preponderance of subsistence farmers in Benue State has resulted in the application of inefficient soil enhancement methods to increase productivity. Farm inputs such as inorganic fertilizer (NPK), herbicides and pesticides have been used over the years without proper feasibility and monitoring which could have adverse effects on floodplain ecosystems and human consumption (Uwah et al., 2007).

It is therefore necessary to analyse floodplain soils used for crop cultivation including cassava which has become a major cultivated crop in Benue State and Nigeria. This is because floodplain soils have become prone to physical and chemical degradation due to perennial crop cultivation and unwholesome farm practises. Studying the River Benue floodplain soils will reveal fertility status, appropriateness for crop cultivation

Table 2. Production output of major crops in Benue State (2009-2012) (Benue State Ministry of Agriculture, 2013).

Crop	Output ('000 Metric tons)			
	2009	2010	2011	2012
Maize	148.61	175.94	139.56	162.53
Millet	65.40	66.15	65.18	69.05
Sorghum	192.46	199.65	191.70	198.60
Rice	289.66	327.27	227.73	397.79
Cassava	3,643.66	3,721.62	3,559.48	3,597.28
Yam	2,902.80	2,954.41	2,874.34	2,994.30
Ginger	3.12	5.69	0.27	0.97
Melon	41.65	44.32	29.16	38.36
Tomatoes	52.29	66.36	18.85	19.86
Sesame seed	47.95	55.52	40.45	41.45
Groundnut	371.82	414.59	358.27	365.45
Soybeans	181.68	196.60	169.68	108.67
Citrus	32,187	31,953.4	1,067.13	1,102.35
Mangoes	11,135	12,678.4	986.35	832.30

including cassava, and physical and chemical deficiencies which require enhancement. Upon these premises, further analysis and appropriate soil management measures can be recommended.

MATERIALS AND METHODS

Study area

The study was carried out at Makurdi, Tarka, and Gboko Local Government Areas (LGAs) of Benue State Nigeria. The majority tribes are Tiv and Idoma. These Local Government Areas are located within the floodplains of the Lower River Benue Basin between Latitudes 7° 13'N and 8° 00'N and Longitudes 8°00'E and 9°00'E.

According to Ayoade (2004), the climate of the area is the tropical wet and dry type, Koppen's Aw classification, with double maxima. The rainy season usually lasts from April to October with an average annual rainfall of 1,332 mm. Precipitation is usually lowest in December. The mean annual temperature is about 27.2°C with an average annual humidity of 59.6%, and mean monthly sunshine of about 7 h. The areas have five months of dry season (November – March) and consists of guinea savannah vegetation type with scattered woodland, shrubs and grassland.

In terms of geology, it is a sedimentary basin that is made up of alluvium, shale, sandstones, siltstones and coastal sand plains, as well as ferruginous soils which can be subdivided on the basis of texture of the surface horizon into hydromorphics, lithosols and laterites. The land is generally low lying (averaging 100 to 250 m) and gently undulating (Kogbe, 1989). River Benue is the dominant geographical feature in the state. River Benue rises from the Adamawa Plateau of Central Cameroon, then flows west across Central Nigeria, and joins River Niger as the main drainage feature in the area. It is one of the few large rivers in Nigeria. The Katsina-Ala is the largest tributary of the River Benue. The floodplains of the River Benue are characterized by extensive swamps and ponds which have potential for dry season irrigated farming.

Sample collection

A total of 12 soil samples were collected randomly from cassava farms in Makurdi, Tarka, and Gboko Local Government Areas. These farms belonged to farmers who are members of farming cooperative societies within the study area. Soil samples were collected at a level of 0 to 30 cm since it was for agricultural purposes. Soil samples were collected at both the surface (0 to 15 cm depth) and subsurface (15 to 30 cm depth) at each sampling point. The soil samples were collected with the soil augur and preserved in foil papers and properly labelled black polythene bags and transported to the laboratory for analysis.

Physical analysis

Soil samples were air-dried and ground with a wooden roller before sieving with a 2 mm mesh. The particle size distribution of the soils was determined using the Bouyoucos hydrometer method (Gee and Bauder, 1986). Sodium hexa-metaphosphate was used as a dispersant after which the textural classes was determined using the textural triangle chart developed by the United Stated Department of Agriculture (USDA, 1996).

Chemical analysis

The pH of soil was measured using the soil/water ratio of 1:2 method of the International Institute of Tropical Agriculture (IITA, 1979). Soil organic carbon was determined using the method of Walkley and Black (1934). Total nitrogen was determined by the micro-Kjeldahl digestion method (Jackson, 1962) while available phosphorus was determined using the Bray and Kurtz (1945) No. 1 method. Exchangeable bases (Ca, Mg, K and Na) were extracted from ammonium acetate buffered at pH 7 (neutral IM NH_4OAc, pH 7.0), flame photometry, and versenate EDTA titration method as prescribed in Jackson (1962) and IITA (1979). The effective cation exchange capacity (CEC) was determined through the summation of exchangeable bases.

Micro-nutrients in the soils (Fe, Mn, Ni, V, Co, and Mo) were extracted by digesting the samples with a mixture of concentrated nitric acid (HNO_3) and hydrogen chloride (HCl) and their concentrations determined by Atomic Absorption Spectrophotometry (AAS) method - Buck Scientific 200A flame atomization prescribed by Barnshiesel and Bertsch (1982). Quality assurance was

Table 3. Location and particle size characterisation of soils samples from cassava farm sites.

Farm site	Crop	Depth (cm)	GPS coordinates		Particle size distribution (%)			Textural class (USDA)	Silt/Clay ratio
			Northings	Eastings	Sand	Silt	Clay		
MKD C1	Cassava	0-15	7.835757	8.5862	87.00	8.00	5.00	Ls	1.60
		15-30			77.00	13.00	10.00	Sl	1.30
MKD C2	Cassava	0-15	7.835332	8.5861	85.00	7.00	8.00	Ls	0.88
		15-30			74.00	15.00	11.00	Sl	1.36
TRK C1	Cassava	0-15	7.66213	8.83203	68.00	29.00	3.00	Sl	9.67
		15-30			68.00	28.00	4.00	Sl	7.00
TRKC2	Cassava	0-15	7.66526	8.83358	68.00	22.00	10.00	Sl	2.20
		15-30			62.00	24.00	14.00	Sl	1.71
GBKC1	Cassava	0-15	7.31069	8.98387	76.00	22.00	2.00	Ls	11.00
		15-30			72.00	22.00	6.00	Sl	3.67
GBKC2	Cassava	0-15	7.31024	8.98401	74.00	20.00	6.00	Sl	3.33
		15-30			70.00	21.00	9.00	Sl	2.33

MKD: Makurdi farm sites; Ls: Loamy sand; Sl: Sandy loam; TRK: Tarka farm site; Sl: Sandy loam; L: loam; GBK: Gboko farm site; Ls: Loamy sand; Sl: Sandy loam.

Table 4. Texture of soils samples collected from cassava farm sites.

Parameter	Surface soil		Subsurface soil	
	Range	Mean	Range	Mean
Sand (%)	68.00-87.00	73.42	62.00-77.00	72.18
Silt (%)	8.00-29.00	19.25	13.00-28.00	20.27
Clay (%)	2.00-10.00	7.33	4.00-14.00	7.55

guaranteed by laboratory officers through double determinations and use of blanks for correction of background. The unit of measurement for exchangeable elements was centimoles of positive charge per kilogram (cmol kg^{-1}) while other elements such as phosphorus and micro-nutrient were measured at milligrams per kilogram (mg kg^{-1}). Measures of central tendency such as mean, averages, and range, were used for analyse and results were presented in tabular and graphic form.

RESULTS AND DISCUSSION

Physical properties

The soil texture of the soil samples from cassava farm sites in Makurdi, Tarka, and Gboko were mostly sandy loam and loamy sand (Table 3). The sand fraction of soils collected from cassava farm sites ranged from 68 to 87% with a mean of 73.42% for surface soils and 62 to 77% and a mean of 72.18% for subsurface soils (Table 4). These soils have low water holding capacity, good drainage and aeration. The soils textures observed have capacity to retain nutrients moderately. Sandy loam and loamy sand soils appear moderately suitable for irrigation, but may be drought prone (Utsev et al., 2014).

Chemical properties

The occurrence of soil pH, total nitrogen, organic carbon, and available phosphorus in Makurdi, Tarka, and Gboko are presented in Figure 1. Soils from Gboko were more acidic but had the highest amount of nitrogen and organic carbon. Soils from Tarka had the least amount of available phosphorus and soils from Makurdi had the least amount of nitrogen and organic carbon.

Soil pH

The chemical properties of soil samples collected from cassava farm sites were summarized with permissible limits and presented in Table 5. The pH of soils collected from cassava farms were slightly acidic and ranged from 5.1 to 6.1 with a mean of 5.7 for surface soils and a range of 5.2 to 6.1 with a mean of 5.7 for subsurface soils. The pH of soils collected from cassava farms were slightly acidic as a result of leaching of appreciable quantities of exchangeable base forming cations such a calcium, magnesium, potassium and sodium from the surface layers of the soils and high buffering capacity. This was

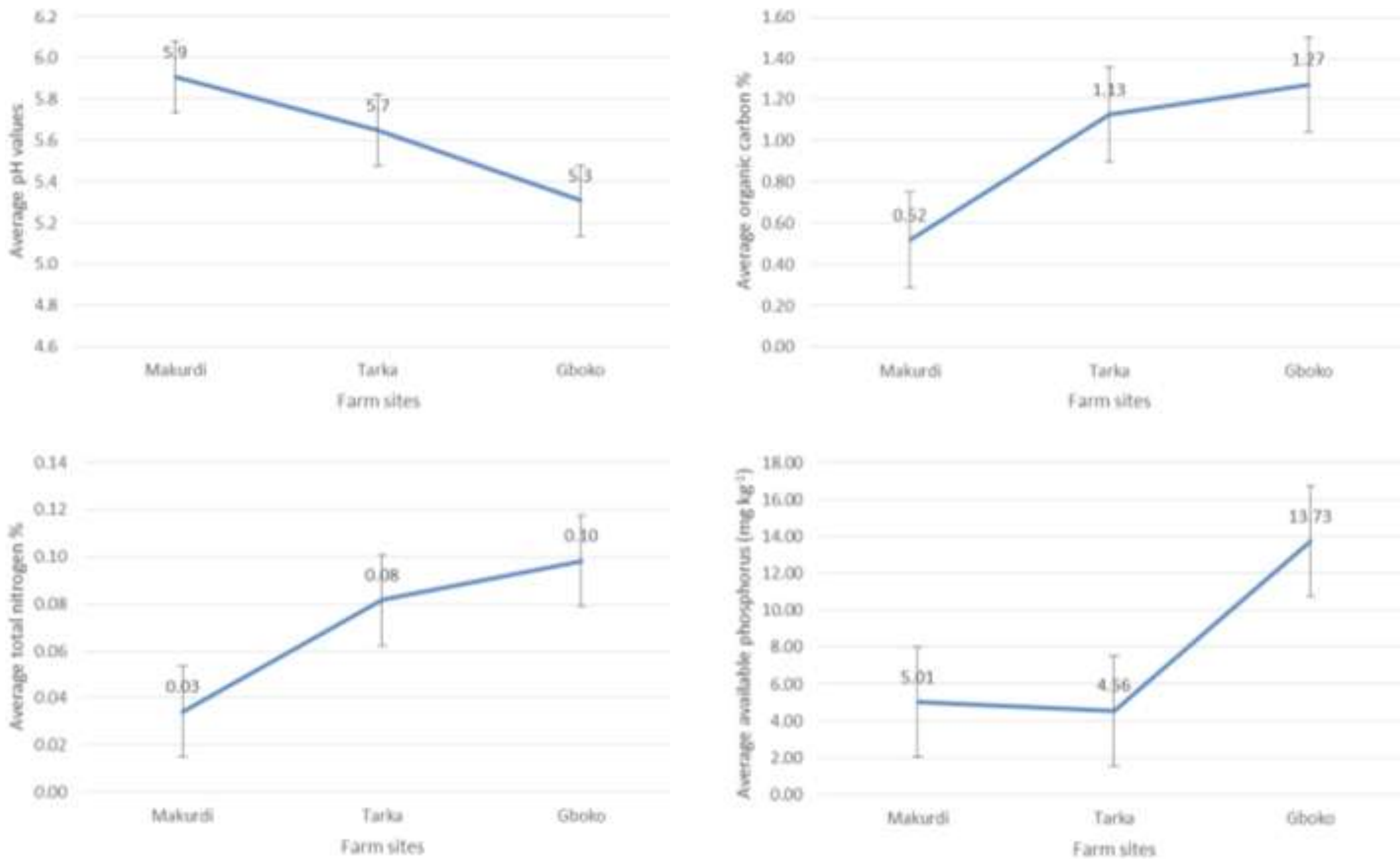

Figure 1. Graph showing soil nutrient values in Makurdi, Tarka and Gboko.

observed elsewhere in the Lower River Benue Basin (Akpan-Idiok et al., 2013; Utsev et al., 2014). Literature reported that cassava tolerates soils within a wide pH range (4.0 to 8.0) but the best pH range for growing cassava is 5.5 to 6.5 (Titus et al., 2011). The pH of these soils is therefore suitable for cassava cultivation.

Organic carbon and total nitrogen

The organic carbon content of samples from cassava farms ranged from 0.44 to 1.04% with a mean of 0.7% for surface soils, and a range of 0.46 to 0.93% with a mean of 0.72% for subsurface soils. The percentage of organic carbon was moderate, but did not meet the acceptable limit of 2% as referenced in Table 5. The total percentage of nitrogen ranged from 0.03 to 0.09% with a mean of 0.05% for surface soils, and a range of 0.03 to 0.08% with a mean of 0.05% for subsurface soils. The organic carbon content and total nitrogen were quite low. This has been attributed elsewhere (Akpan-Idiok et al., 2013) to poor vegetative growth, fast rate of decomposition, and the high temperature of the ecological zone. However, the low content of nitrogen in the study area could be attributed to burning of bush and plant residue during the farming season, leaching and the high rate of organic matter decomposition by micro-organisms, as well as, rapid mineralisation and absorption of nitrogen due to continuous farming. The low levels of organic carbon and total nitrogen cannot sustain intensive cropping, and the application of inorganic fertilizer such as NPK is necessary (Abua and Edet, 2013).

Available phosphorus

Available phosphorus in the soil samples from cassava farms ranged from 1.62 to 42.37 mg kg^{-1} with a mean of 8.48 mg kg^{-1} for surface soils, while subsurface soils had a range of 1.00 to 13.50 mg kg^{-1} with a mean of 5.66 mg kg^{-1}. Available phosphorus levels below 20 mg kg^{-1} (Holland et al., 1989) are a limitation to successful crop production and therefore such soils should be enhanced with fertilizers. The low content of available phosphorus can be explained by the high phosphorus absorption capacity of the soils, and the slight acidity of the soils prevalent in floodplain soils.

Table 5. Chemical properties of soils from cassava farm sites in Makurdi, Tarka, and Gboko.

Parameter	Surface soil		Subsurface soil		Maximum permissible limits
	Range	Mean	Range	Mean	
pH	5.1-6.1	5.7	5.2-6.1	5.7	5.1-6.5
Organic Carbon (C) (%)	0.44-1.04	0.7	0.46-0.93	0.72	2.0 (%) ++
Total Nitrogen (N) (%)	0.03-0.09	0.05	0.03-0.08	0.05	0.2 (%) ++
Available Phosphorus (P) (mg kg^{-1})	1.62-42.37	8.48	1.00-13.50	5.66	20 (mg kg^{-1}) +++
Calcium (Ca) (cmol kg^{-1})	2.11-3.80	3.3	2.80-4.60	3.28	10-20 (cmol kg^{-1}) +++
Magnesium (Mg) (cmol kg^{-1})	1.36-2.40	2	1.80-2.26	1.96	3-8 (cmol kg^{-1})
Potassium (K) (cmol kg^{-1})	0.06-0.10	0.09	0.05-0.14	0.09	0.6-1.2 (cmol kg^{-1}) +++
Sodium (Na) (cmol kg^{-1})	0.05-0.07	0.06	0.04-0.09	0.06	0.7-1.2 (cmol kg^{-1}) +++
Exchange Acidity (cmol kg^{-1})	0.6-0.96	0.77	0.86-1.06	0.92	4.1 (cmol kg^{-1}) +++
ECEC (cmol kg^{-1})	4.78-7.13	6.3	5.83-7.96	6.23	10.00 (cmol kg^{-1}) +++
Base Saturation (%)	86.00-88.00	86.58	85.00-88.00	86.55	60-80 (%) +++
Fertility indices					
Calcium/Magnesium ratio	0.94-2.43	1.69	1.32-2.09	1.7	3:1-5:1
Magnesium/Potassium ratio	17.50-37.50	24.22	16.14-37.20	23.73	1:2
Carbon/Nitrogen ratio	11.0-16.0	14.33	12.0-17.0	14	25

++ FPDD (1990), +++ Holland et al. (1989).

Exchangeable bases and exchange capacity

The level of exchangeable bases (Ca, Mg, K, and Na) were moderate with mean values of 3.3, 2, 0.09, and 0.06 cmolkg^{-1} for surface soils and 3.28, 1.96, 0.09, and 0.06 cmol kg^{-1} for subsurface soils, respectively. Calcium and magnesium were the dominant cations, while potassium and sodium had low concentrations (Table 5). This was also reflected in the moderate levels of the effective cation exchange capacity (ECEC) which ranged from 4.78 to 7.13 cmol kg^{-1} with a mean value of 6.3 cmol kg^{-1} for surface soils and a range of 5.83 to 7.96 cmol kg^{-1} with a mean value of 6.23 cmol kg^{-1} for subsurface soils. Exchangeable acidity (Al^{3+} and H^{+}) of soils from cassava farms were well below the permissible limit of 4.1 cmol kg^{-1}. Exchangeable acidity ranged from 0.6 to 0.96 cmol kg^{-1} with a mean of 0.77 cmol kg^{-1} for surface soils and a range of 0.86 to 1.06 cmol kg^{-1} with a mean of 0.92 cmol kg^{-1} for subsurface soils.

Base saturation

The base saturation percentage of the soils were high and ranged from 86 to 88% with a mean of 86.58% for surface soils and a range of 85 to 88% with a mean value of 86.55% for subsurface soils. These base saturation results are above the recommendations in Holland et al. (1989) and indicate the presence of good amounts of soluble forms of basic cations in soil solution. This kind of situation enhances the availability fertilizers in soil for crop uptake. It is generally accepted in literature that soils with base saturation percentages over 50% are fertile soils. The fertility indices of soils from cassava farm sites as presented in Table 5 also support this assertion. These soils however require fertility enhancement with organic/inorganic fertilizers for optimal crop production.

Micro-nutrients

Micro-nutrients in this study are metals that are required by the body in trace quantities and are essential for maintaining various body functions and metabolic activities. The micro-nutrients analysed in this study were iron (Fe), manganese (Mn), nickel (Ni), vanadium (V), cobalt (Co), and molybdenum (Mo) as stated in the methodology section. According to the National Academy of Science/Institute of Medicine (NAS/IOM, 2003), the biological functions of micro-nutrients in plants, animals and humans are still under research. However, Lokeshappa et al. (2012) stated that toxicity of micro-nutrients in farm produce depend largely on crop exposure to soils that have been contaminated, hence the need for periodic monitoring. The ranking of micro-nutrients in order of concentration was Fe>Ni>Mn>Mo>Co>V. The values of micro-nutrients (Fe, Mn, Ni, V, Co, Mo) analysed for soils from cassava farm sites were all below tolerable limits as referenced in Table 6. The comparative graphs for micro-nutrient occurrence in Makurdi, Tarka, and Gboko are presented in Figure 2. Tarka Local Government Area had higher occurrence of most of the micro-nutrients analysed.

The need for effective soil management

Cassava extracts enormous amounts of nutrients from

Table 6. Micronutrients of soils from cassava farm sites in Makurdi, Tarka, and Gboko.

Parameter	Surface range	Mean	Subsurface range	Mean	Maximum tolerable limits
Iron (Fe)	201.06-900.48	589.09	429.23-900.49	560.78	10,000-100,000 mg kg^{-1}*
Manganese (Mn)	10.10-26.13	21.13	13.24-40.10	21.8	200-2000 mg kg^{-1}**
Nickel (Ni)	29.21-56.20	40.32	20.06-54.60	39.91	10-1000 mg kg^{-1}**
Vanadium (V)	0.09-0.16	0.12	0.05-0.22	0.12	20-500 mg kg^{-1}**
Cobalt (Co)	0.38-0.73	0.61	0.43-0.78	0.6	1-70 mg kg^{-1}**
Molybdenum (Mo)	1.09-2.29	1.4	0.20-1.89	1.32	4 mg kg^{-1}

*Brady and Weil (1996), ** Bohn et al. (1985).

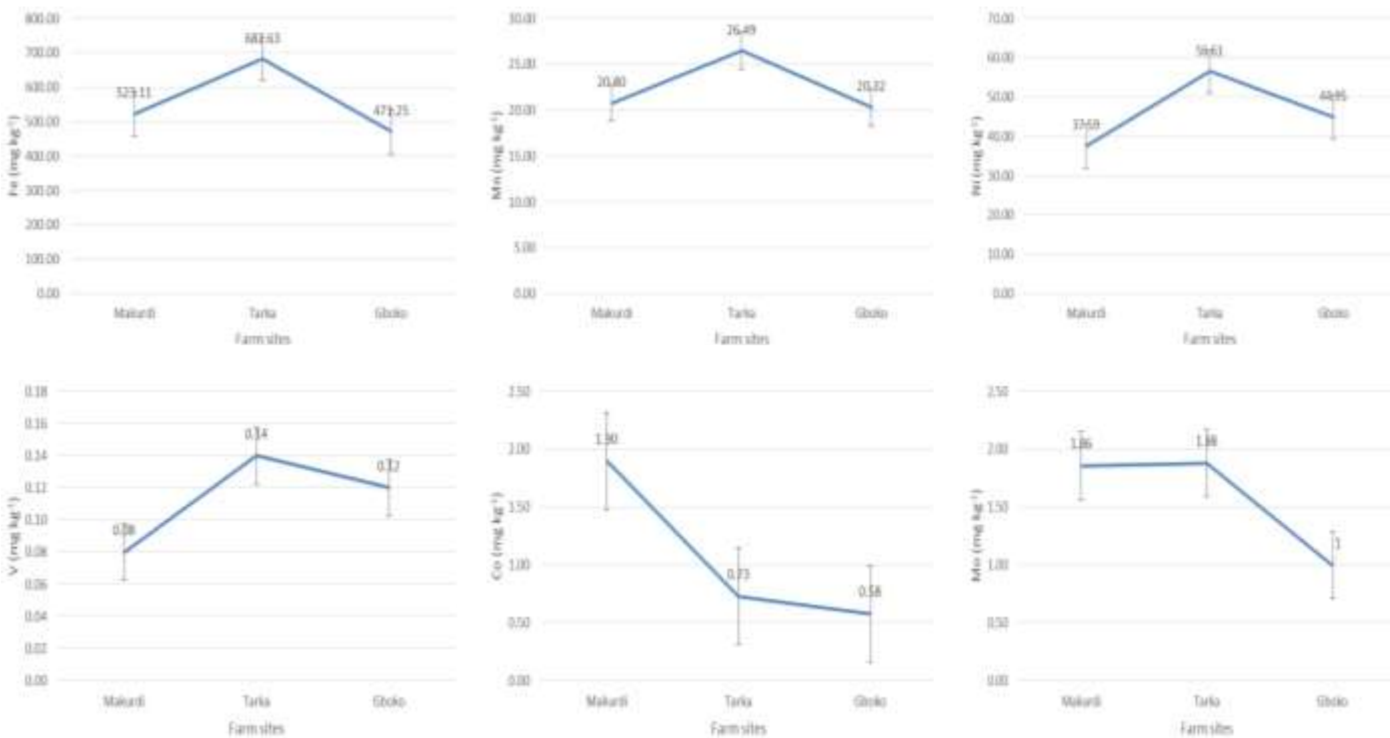

Figure 2. Graph showing values of micro-nutrients in Makurdi, Tarka, and Gboko.

the soil notwithstanding that it can grow on soils with low nutrient levels. Therefore, effective application of fertilizer assures healthy plant growth capable of resisting pests and diseases (Rio, 2012). According to Rio (2012), nutrient deficiency affects the cassava plant in several ways (Table 7).

The result of the study demonstrates that these soils are suitable for crop cultivation including cassava. However, the values of parameters measures reveal deficiencies in nutrient availability for optimal crop yield. The River Benue floodplain is an area of perennial crop cultivation and the use of inorganic fertilizer is already an annual occurrence. The cultivation of cassava crops in ecosystems with the reported level of deficiencies may witness low crop yields. The aggressive utilization of nutrients by root crops such as cassava could exacerbate the degradation of soil physical and chemical composition. Without effective application of inorganic fertilizer in fragile ecosystems such as floodplains, the risk of attendant pollution such as buildup of soil chemicals and water pollution is imminent. A similar study by Abah et al. (2013) assessed amounts of micro-nutrients in soils and roots and cassava grown in farms where agrochemicals have been used in parts of Benue State. The study by Abah et al. (2013) revealed widespread inefficient application of inorganic fertilizer

Table 7. Attributes of cassava plant faced with nutrient deficiency (Rio, 2012).

Parameter	Deficiency attributes
Soil pH	Reduced growth and yield in soils with pH outside 5.5-6.5
Nitrogen	General yellowing of plants; reduced plant and root growth; and stunting of plant
Phosphorus	Leaf tips look burnt; reduced plant growth and yields; and thin stems narrow leaves and fewer lobes
Potassium	Wilted and scorched leaves; crooked upper stems with grooves and interveinal from leaves; and reduced plant height and vigour
Calcium	New leaves at the top of the plant are distorted or irregularly shaped; and poor root formation
Magnesium	Interveinal chlorosis from tip or edges and advancement towards the centre; and leaf margins may become necrotic
Iron	Uniform chlorosis of leaves; and reduced plant and leaf size
Manganese	Interveinal chlorosis of young fully expanded leaves; reduction in size of plant leaves, shoots, and tubers; and dead spots or parches appear

and herbicides which had caused a buildup of micro-nutrients in soils and cassava roots. Abah et al. (2013) called for the education of farmers on efficient use of agrochemicals.

Another study by Babalola et al. (2011) assessed the soils of two wetlands in Nigeria for rice production. Babalola et al. (2011) stated that site specific soil assessments were more beneficial to crop production and revealed that soil infertility, especially regarding soil pH, potassium, and nitrogen, as the limiting factor for rice production. It therefore means that optimizing the level of chemicals such as nitrogen, potassium, and phosphorus would add to the fertility quality of these soils. The most uitlised method for this approach is the application of inorganic fertilizer such as NPK. The efficient use of inorganic fertilizer has been emphasized in literature. Babalola et al. (2011) recommended fertility evaluation studies and the efficient use of appropriate fertilizers.

A study by Chukwu (2007) assessed soils in wetlands in Southeastern Nigeria and recommended increased use of bio-fertilizers such as Azolla as a supplement to inorganic fertilizers. A change in farming method as reported elsewhere (Nwite et al., 2013) reduces the overdependence on inorganic fertilizer and depletion of nutrients. Nwite et al. (2013) observed that rice farmers in inland valleys of Southeastern Nigeria alternated between various methods to prevent leaching and dependence on inorganic fertilizer. Shifting cultivation as a way of preserving soil fertility on floodplains was reported by Zarin et al. (2006). Zarin et al. (2006) concluded that flooding and fluvial erosion had more significant effects on soil fertility in floodplains than continuous cultivation.

The efficient application of inorganic fertilizers to optimize soils fertility has drawn the attention of scholars for some time now. According to Finke and Stein (1994), optimizing soil fertility could result in leaching and contamination of soils as it is quite difficult to strike a balance between actual nutrient requirements and plant uptake. Finke and Stein (1994) proposed site specific assessment of nutrient requirements and efficient application of fertilizers.

Given the result of this paper, the use of inorganic fertilizers is inevitable. This is because, even though the soils were found to be suitable for crop cultivation including cassava, total nitrogen, organic carbon, and available phosphorus were found to be inadequate and varied in Makurdi, Tarka, and Gboko. This study therefore strongly recommends that all farmers should identify the nutrient requirements of farm soils before embarking on the use inorganic fertilizers. Governments should establish or collaborate with relevant laboratories to make periodic soil analysis available to farmers at subsidized rates depending on local economic realities. Agricultural extension services should be active in areas of intensive crop farming to provide guidance on efficient application of agrochemicals and evaluation of compliance. Subsistence farmers require adequate support from both the public and private sector to improve cultivation methods and practices. This will engender a culture of efficiency and productivity with long term benefits for sustainable agriculture.

Conflict of Interests

The authors have not declared any conflict of interests.

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