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An overview: Soybean and Biological Nitrogen Fixation

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Abstract
Legumes belong to leguminosae family, which is one of the largest and most important families of flowering plants. The present review describes the history, consumption, nutritional aspects, and commercial aspects of soybean. Soybean is the world's foremost provider of vegetable protein, oil and unique among the legumes belongs to the family Leguminosae and subfamily Papilionaceae. Soybean occupies a premier position among agricultural crops. Soybeans are unique among the legumes because they have high biological nitrogen fixation. It has been observed that formation of more nodules determine the fixation of nitrogen
Keywords: Legumes, Soybean, Biological, Nitrogen, Fixation, Nodules

Introduction

As early as 5,000 years ago, farmers in China grew soybeans. In 1804, a Yankee clipper ship from China brought soybeans to the U.S. And in 1829, U.S. farmers first grew soybeans. They raised a variety for soy sauce. During the Civil War, soldiers used soybeans as "coffee berries" to brew "coffee" when real coffee was scarce. In the late 1800s, significant numbers of farmers began to grow soybeans as forage for cattle. In 1904, at the Tuskegee Institute in Tuskegee, Alabama, George Washington Carver began studying the soybean. His discoveries changed the way people thought about the soybean; no longer was it just a forage crop (Dugje *et al.,* 2019). Now its beans provided valuable protein and oil. By 1929, U.S. soybean production had grown to 9 million bushels. That year, soybean pioneer William J. "Bill" Morse left on a two-year odyssey to China during which he gathered more than 10,000 soybean varieties for U.S. researchers to study. Prior to World War II, the United States imported 40% of its edible fats and oil. At the start of the war, this oil supply was cut. Processors in the U.S. turned to soybean oil for their supply. The late type soybean from South China was found closer to the wild type and it is expected that wild soybean is a common ancestor for cultivated type of South China, from which early cultivated types originated during the process of dissemination to North China (Gai et al. 2000). The higher genetic diversity among the South China population compared to North China population also supported the origin of soybean in South China (Ding et al. 2008). Legumes include peas, beans, soybean, lentils, peanuts, and other podded plants that are used as food. Legumes have been cultivated for thousands of years, although many of the varieties of beans and peas that are common place today were unknown until relatively recent times. Legumes have played an important role in the traditional diets of many regions throughout the world. It difficult to think of the cuisines of Asia, India, South America, the Middle East, and Mexico without picturing soybeans, lentils, black beans, chickpeas, and pinto beans, respectively. Legumes contain 390 – 510g/kg starch content as an important energy source. This legume starch is characterized by high amylopectin content. The oil content of legumes (except soy and lupin) is about 1 – 2% which is mainly composed of poly unsaturated fatty acids.

Soybean

Soybean is the world's foremost provider of vegetable protein, oil and unique among the legumes belongs to the family Leguminosae and subfamily Papilionaceae. Soybean (*Glycine max* (L.) Merrill.) occupies a premier position among agricultural crops. The genus *Glycine* consists of two subgenera: *Glycine* (perennials) and *Soja* (annuals). The perennials consist of 22 recognized species and the annual two species, *G. max* L. Merrill. (cultigen) and *G. soja* Sieb & Zucc (wild species and progenitor of *G. max*) The bushy, green soybean plant is a legume related to peas, groundnuts (peanuts) and alfalfa. Soybeans are included in the category of oilseed,

which is a generic reference to crops with seeds that can produce edible and/or non-edible oil in economic quantities. (Hymowitz, 2004).

Description of Soybean

Soybean is a hairy annual with an extensive tap root system, most of it in the top 15 cm of the soil. The tap root may grow as deep as 2 m and adventitious roots grow from the hypocotyls (Chaturvedi *et al.*, 2011). Cultivated soybeans have an erect growth habit though procumbency is not uncommon in germplasm resources (Davis, 1987). The modern cultivars of soybean are mostly erect, bushy, 20–180 cm tall, usually with a few primary branches and no secondary branches. Exceptionally prostrate and freely branching forms are also found, particularly in those varieties which are meant for forage purposes. The leaves are trifoliate and alternate with long petioles and small stipules and stiples; the leaflets are ovate to lanceolate with mucronate tip.

In soybean, flowering and maturity are greatly influenced by photoperiod. The flowers are typical papilionaceous, white or pale purple, with a tubular calyx of five unequal sepal lobes and a five-member corolla that consists of a posterior standard petal, two lateral wing petals and two anterior keel petals (Guard 1931). The androecium is diadelphous with 9 + 1 arrangement. The single pistil is unicarpellate and has 1–4 campylotropous ovules (Palmer 2001). The style curves back toward the posterior stamen and is surrounded by a knob-like stigma (Carlson and Lersten, 1987). Each flower is subtended by two bracteoles and has a hairy calyx of five pointed sepals united for about half of their length. The pods are short stalked and occur in groups of 3–15, 3–7 cm long and hairy, light brown at maturity and slightly constricted between the seeds. The seeds vary greatly in shape, size and colour though these are mostly often round and yellowish, brown or black with epigeal germination. Soybeans are mostly self-pollinated, though rates of natural cross-pollination have been observed to be between 0.03 and 1.14% in natural conditions (Culter 1934; Caviness 1966). The wild annual soybean, *G. soja* is predominantly self pollinated, while the perennial wild relative, *G. argyrea* (Ting.) and its closely related species, *G. clandestine* (Wendl.), have both self-fertilized cleistogamous as well as chasmogamous flowers on the same plant (Brown *et al.*, 1986 and Palmer *et al.*, 2001). The chasmogamous flowers are frequently visited by insect pollinators leading to cross-pollination. Small insects such as thrips and honeybeas are mainly responsible for natural outcrossing in soybean, but other insects are also observed to be working on soybean flowers. Insect-mediated cross pollination in soybean has been discussed in detail by Palmer *et al*., (2001). Self pollinating soybean flowers have 3–4 ovules, which reach maturity prior to anthesis (Stelly and Palmer 1985). Flowers open and normally self-pollinate at anthesis. For planned controlled pollination, first the sepals and petals are carefully removed from the young unopened flowers. This is followed by removal of anthers by forceps or tweezers though removal of anther is not always necessary (Stelly and Palmer 1985).

The remaining flowers on the inflorescence are also removed. Pollination is done the next morning. For this, the flowers which are about to open should be taken. In these, with the help of forceps, first sepals are removed, followed by removal of the standard petal, wing and keel petals to expose the anthers. These anthers are then gently brushed on the stigma till the pollen is clearly visible on it. A small pod is usually visible in 6–7 days.

Economic Importance of Soybean

Soybean is among the major industrial and food crops grown in every continent. The crop can be successfully grown in many states in Nigeria using low agricultural input. Soybean cultivation in Nigeria has expanded as a result of its nutritive and economic importance and diverse domestic usage. It is also a prime source of vegetable oil in the international market. Soybean has an average protein content of 40% and is more protein-rich than any of the common vegetable or animal food sources found in Nigeria. Soybean seeds also contain about 20% oil on a dry matter basis, and this is 85% unsaturated and cholesterol-free. The best-known and most widely used products from soybeans are soybean oil and soybean meal. Soybean oil is the most widely used edible oil in the world and soybean meal is the leading protein and energy source for animal feeds. Soybean oil is used as cooking oil and as the base for shortening, margarine, salad dressings and mayonnaise. Lecithin extracted from soy oil during the refining process performs as an emulsifying agent and when further processed is an important ingredient in confections, baked foods, dairy products and instant foods. Lecithin is also used in animal feed, health and nutrition products, cosmetics and industrial coatings. A rapidly growing market for soybean oil is found in the manufacture of a variety of pharmaceuticals, such as vitamin E and other anti-oxidants, as inexpensive aids to good health. Soybean oil is also used for industrial applications such as a basicinsi[b8-5(pp)4(l)-5(ic)-31)6(r5488-5(ppl)-5(ic)x)-15-70(Soyb 0 s)-3(oSoyb 0th)-10us pistils (pr)6(o)-10(duc)-5(ts)-

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Nitrogen Fixation by Some different Legumes

Common Name	**Scientific Name**	**Average**	**Range**
		Kg N/ha	
Soybean	*Glycine max*	95	14-300
Peanut	*Arachis hypogaea*	124	100-152
Cowpea	*Vigna sinensis*	198	73-354
Pigeon pea	*Cajana cajan*	224	168.280
Chick pea	*Clcer arietmum*	103	

Source: Elkan, 1992; Romain, (2001)

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Analytical Quality Control Measures in the Determination of Heavy Metals in Soil: A Review

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Abstract
In environmental monitoring, such as the determination of heavy metals concentrations in soils, each aspect of the monitoring program, from sample collection to data management, must address and meet applicable quality standards. This paper reviews the literatures on the importance of Quality Control in the determination of heavy metals concentration in soil. The significance of these metals in soil as well as in humans was highlighted.
Keywords: Heavy metals, soil, Quality Control, Reference Materials

Introduction

Decisions on the environment are made based on the assumption that analytical results are the best possible, within known limits of accuracy and precision, which are representative of site conditions (International Atomic Energy Agency, 2003). This can be achieved through effective use of Analytical Quality Control measures in the determination processes (Wood & Botha, 2014).
The analytical procedures for the elemental analysis of soil require some steps in the determination process starting from sample processing and preparation which involve drying of the sample after collection, partial or total breakdown of the sample matrix, known as digestion and determination by instrumental methods. All these steps introduce error in the determination process which must be quantified using appropriate Quality Control measures either through the use of blank samples, replicate samples or and Reference Material (Musa *et al.,* 2017). Knowledge of the errors in the analytical processes and procedures in the laboratory provide the best possible way(s) to avoid faulty result that may lead to wrong decision which could have adverse effect on humans and other living organisms (International Organization of Standard 9001, 2000).

Heavy Metals in Soils

Heavy metals are defined in various ways based on its properties lie atomic weight, density and toxicity (Lakshmi & Sung-Ok, 2016). They were defined as metallic elements with relatively high density compared to water (at least 5 times greater than the density of water) with assumption that heaviness and toxicity are inter-related (Tchounwou *et al*., 2012, Onakpa *et al*., 2018).To buttress this, Jarup (2003) and Abdulrashid et al. (2017) defined heavy metals as chemical elements that have relatively high atomic weight and density of more than 5 g cm^{-3}.Examples of heavy metals are cadmium, arsenic, chromium, lead and many others (Sanuade *et al*., 2017). Since heavy metals areelements that have atomic weights greater than 55 according to Lymperopoulou et al. (2014), it implied that micronutrients such as copper (atomic weight 63.54), iron (atomic weight 55.85), Manganes (atomic weight 54.993), and Zinc (atomic weight 65.38) are also identified as heavy metals. Heavy metals also have the characteristic that they donot leach into the soil from the top soil which make them present at a higher concentration in the surface soil where most plants take up nutrients for growth (Taghipour *et al*., 2013).
Heavy metals are widespread and are of great environmental concern as they are persistent, non-degradable and toxic (at a concentration higher than the acceptable limit) (Liatu *et al*., 2017, Abdulrashid *el al*., 2017 and Khadeeja *et al*, 2013). Accumulation of large amount of these heavy metals in human through the consumption of plants and animal contaminated with the metals or direct exposure from the environment can cause acute and chronic toxicity (Addis &Abebaw, 2017). Heavy metals are known to react with nuclear proteins and DNA resulting in oxidative deterioration of biological macromolecules resulting if effects like mental lapse, kidney failure, bone fractures, darrhoea, stomatitis, tremor, hemoglobinia ataxia, paralysis, depression, pneumonia,

central nervous system disorder and cancer in human and higher animals (Addis &Abebaw, 2017, Taghipour *et al*., 2013 and Helaluddin *et al*., 2010).

Heavy metals gain access into the environment from both natural and anthropogenic sources (Liatu et al., 2017). Soils, regarded as useful for the sustainability of life, get contaminated when they are exposed to activities such as mining, disposal of high metal wastes, use of leaded gasoline, use of pints with high concentration of heavy metals, application of phosphate based fertilizer which are often contaminated with heavy metals, pesticide application, spillage of petrochemicals and oils and many industrial activities (Wuana and Okieimen, 2011). The measurement of the concentration of elements in soils is the first step in evaluating their health or ecological hazard (Gaudino *et al*., 2007). It is therefore important to accurately know the levels of these heavy metals present in soil for appropriate decision to be taken at the right time (Addis &Abebaw, 2017). To effectively do this, analytical errors that could result in the course of analysis need to identified and eliminated or reduced (Rahman, 2011).

Sources of Errors in Analytical Processes

Error is defined as the difference between a measured value and the true value. It denotes the estimated uncertainty in a measurement. It is impossible for a chemical analysis to be performed without errors or uncertainties but it can be minimized and the size estimated with acceptable accuracy (Ellison & Hardcastle, 2012). Two term are commonly associated with error which are accuracy and precision. Precision is the reproducibility of a measurement result while accuracy is the closeness of the measured value to the true value (Rahman, 2011).

There are different causes of analytical errors and they can be divided into three. They are:

I. preanalytical stage errors,
II. analytical stage errors and
III. post analytical stage errors(International Organization of Standard 9001, 2000).

Errors could arise in the pre-analytical stage as a result of faulty primary samplingin the form of incorrect sampling device, inappropriate container for sample storage, cross contamination during sampling, poor adherence to sampling protocol, collection of sample that is not representative, misidentification of sample due to incomplete sample label, incorrectly labeled sample container, partly erased or illegible label and disparity between label and analytical parameters on the request form and samples. Also, faulty sample transportation and storage which could be fromleakage in storage container, incorrect storage temperature, long storage and transportation time, inappropriate transport container and condition.Another pre-analytical stage sources of error is faulty sample preparation or processing which could result from drying, cleanup, milling or grinding, mixing or homogenizing, weighing, digestion, extraction, dilution, leaching (Ellison & Hardcastle, 2012 andInternational Organization of Standard 9001, 2000). In the analytical stage, the error(s) may arise from wrong findings when the principle and procedure of the test is not followed strictly; reagents and standards are not prepared and/or mixed properly and QC materials are not used for method and equipment validations; use of method with unacceptable large error, inadequate detection limit of the equipment used, faulty conversion factor, poor or inadequate calibration as a result of inadequate matrix match, incorrect calibration procedure and range. The need for modification of standard is also a analytical stage error if not done as well as inappropriate calibration standard. Error could also be from calculation through the use of incorrect software or calculator, use of incorrect values for the computation of results and the use of wrong unit. Equipment failure and servicing problem as well as wrong instrument setup can result in incorrect analytical result. Another important source of analytical stage error is the environment which could be as a result of cross contamination within the laboratory and inadequate control of ambient conditions. Human error is a major factor to contend with as a source of error in analysis when there is lack of trained or experienced laboratory personnel who will not follow reporting instruction, rush analysis, fail to prepare reagents accurately and carry out proper calibration on instrument and interpret results wrongly among others (Ellison & Hardcastle, 2012 and International Organization of Standard 9001, 2000).

In the post analytical stage, the error(s) may occur if reporting, checking and verifications are not done properly, interpretation of test results are not considered seriously and abnormally or unexpected result is not reviewed and/or performed again(International Organization of Standard 9001, 2000, Wenclawiak et al., 2010). Quality Control programs are designed to minimize these sources of error and to control all phases of the monitoring process (International Organization of Standard 9001, 2000).

Analytical Quality Control and its Importance

Analytical Quality control (AQC) is the application of procedures for controlling measurement process routinely to limit errors and obtain measurements of known and defensible quality. It is a unit of Analytical Quality Assurance (AQA), the overall management system that ensures an AQC program is in place and is working effectively (Maynard & Thomas, 1993). Testing and calibration laboratories, including analytical chemical laboratories, are continually requested to provide evidence on the quality of their operations (International Atomic Energy Agency, 2003) to establish and ensure a highest level of accuracy and precision in

routine measurements (Bunk, 2007). The AQC system is therefore designed to provide routine and consistent checks to ensure data integrity, correctness, and completeness and to identify and address errors and omissions (International Organization of Standard 9001, 2000). According to OVOP (2016), the integrity of analytical result is depends on the adherence to quality control during the analytical processes. Quality Control is very important because "a test wrongly done is worse than a test not done" Quality Control is useful to:

i. ensure and prevent a test from being done wrongly.
ii. detect, reduce and correct deficiencies in laboratories analytical process
iii. ensuring quality test results.
iv. give relevant, reliable, timely test results which provide correct interpretation and decision making.
v. determine precision and accuracy,
vi. demonstrate absence of interferences,
vii. demonstrate absence of contamination (from sampling equipment, glassware, and reagents)

Laboratory Quality Control Measures

The use of blanks: Method and reagent blank are the most common types of blank used in laboratory quality control. Method blankis an analyte-free matrix that is as similar as practical to the test sample which is taken through the same laboratory preparation and analysis process as the samples. A reagent blank consist of the analytical reagent(s) used in the analytical process without the analyte or sample matrix that is introduced into the procedure at an appropriate point and carried out through all the subsequent analytical steps to establish the contribution of the reagent in the analysis of the target analyte (Maynard & Thomas, 1993, General Society of Surveillance, 2016).

There are other types of blank which

i. **Calibration Blank** used to set the zero end of the calibration curve (Environmental Protection Agency, 2018),
ii. **Transportation blank**which is distilled or de-ionized waterin a container that accompanies the sample containers into the field and is returned to the laboratory unopened used to monitor contamination from the sample or shipping container,
iii. **Field Blank which is** distilled and de-ionized water that has been exposed to the same conditions and treatment as the environmental samples used to monitor potential field sampling contamination (Mead, 2019)
iv. **Calibration Check Blank,** an instrument blank (the same blank that used forcalibration) that must be checked for the analyte immediately after calibration and at minimum frequency (after every 10 samples) and at the end of the analysis (General Society of Surveillance, 2018).

Blank determination checks cross contamination, procedure failure,and instrument's instability drift and deterioration.

The use of laboratory Replicate or Split Sample: Replicate sample is homogenous sample that is split in the laboratory into two or more subsamples. Splits can be submitted to different analysts or laboratories which are used to measure or monitor the precision of the analytical methods (Mead, 2019).

The use of Spiked Samples: A spiked sample is a sample to which a known concentration of the target analyte has been added. When analyzed, the difference between an environmental sample and the analyte's concentration in a spiked sample should be equivalent to the amount added to the spiked sample. It is used to provide information on matrixeffects and apparent accuracy. It is a matrix spike if it is an aliquant of the test sample (Maynard & Thomas, 1993, Academic Committee for Quality Assurance, 2008).

The use of Reference Material: Material or substance one or more of whose property values are sufficiently homogeneous and well established to be used for the calibration of an apparatus, the assessment of a measurement method, or for assigning values to materials (Williams, 2014 and International Atomic Energy Agency, 2003).

There are different types among which are:

i. **Certified Reference Materials (CRMs):** Reference material, accompanied by a certificate, one or more of whose property values are certified by a procedure, which establishes its traceability to an accurate realization of the units in which the property values are expressed, and for which each certified value is accompanied by an uncertainty at a stated level of confidence (International Atomic Energy Agency, 2003)
ii. **Quality Control Sample,a**nalysis of which allows the determination of precision, accuracy, sensitivity, and contamination control for the sampling and analysis process (Shukla, 2015) and according to Maynard & Thomas (1993), there are two types of Quality Control (QC) samples which are **Internal QC Sample**, prepared in the laboratory which include blanks, replicates, surrogates, spikes, and Reference Materials (In-house) and **External QC Sample or field quality control samples**, prepared in the field and handled exactly the same way as the collected samples.

Amongst all these methods of Quality checks, the use Reference Materials as blind samples measures accuracy, bias and precision and when used together with some of the quality control measures, a result that is highly dependable will be obtained (Jedrzejczak et al., 1999).

Reference Materials

Reference Materials find their importance in the areas of their application. They are useful as materials that support measurements concerned with chemical composition, biological, clinical, physical, engineering properties, taste and odour (International Atomic Energy Agency, 2003) and hence providing:

(i) confidence in the results generated that they are the very best posible,
(ii) selection of the right laboratory for a project,
(iii) a bases for correct decision making which eventually reduce loss of money, time, enery and valuable resources (Stefanie et al, 2017),
(iv) means of assessing food quality and healthcare decision making (Koch, 2002).

They may be characterized for 'identity' (e.g. chemical structure, fibre type, microbiological species) or for 'property values' (e.g. amount of specified chemical entity, hardness) (International Atomic Energy Agency, 2003).Reference material (RM) that is accompanied by a certificate is referred to as certified reference material (CRM) (Shukla, 2015). The application of certified reference materials (CRMs) in analytical chemistry for quality control purposes is well recognized and recommended by a wide range of international, national and professional organizations (International Atomic Energy Agency, 2003). Several organizations produce CRM of trace metals and organic compounds among which are Community Bureau of Reference (BCR, EU), Mintek South Africa, National Institute of Standards and Technology (NIST, USA), Switzaland EMPA, National Institute for Environmental Studies (NIES, Japan), National Research Council of Canada (NRCC), Sigma-Aldrich and International Atomic Energy Agency (IAEA). However, the current practice in CRM application in many analytical sectors is not adequate because of the cost of this material but with the advent of non-certified Reference Materials also known as Quality Control material or In-House Reference Material which is cheaper to produce compared to CRM, the cost of Quality Control check in laboratories is now reduced and its development for different laboratories is recommended (Marsland, 2000, Asia Pacific Laboratory Accreditation Corperation, 2018 andLlaurado et al, 2001).

In-House Reference Material Development for Heavy Metal Determination

In-house Reference Material, also known as Quality control (QC) sample, check sample, set up sample, is an example of matrix reference material that is developed by a laboratory for its own internal use. An In-House RM is usually developed when the matrices or concentration levels of target analyte of commercially available RMs do not closely match the sample to be analyzed or when a sufficient supply is needed that will be available for many years (Llaurado et al, 2001).

Several works have been done on the production of Soil Reference Materials for metal determination. Samin&Sunanti (2018) developed an in-house zircon minerals Reference Material from Kalimantan (TumbangTiti), and Bangka by obtaining 10 kg of the mineral dried at 90 °C for 6 hours twice, crushed with ball mill, passed through 200 mesh and homogenized with a homogenizer for 6 hours three times. They produced 40 bottles of the prototype In-House Reference Materials with a 100 g capacity each. The product was tested for homogeneity and stability by statistical method of ISO 13528-2008 and ISO 35-2006. The moisture content by gravimetric method, standardization using Certified Reference Material (JCRM R 502 from Japan) and characterization for the oxides using X-Ray Diffraction (XRD) method of the zircon minerals produced were done.

Silva et al. (2017) also prepared and characterized a quality control material according to the specification of International Organization of Standard (ISO) Guide 80 for the determination of inorganic constituents present in a phosphate-bearing rock that is used for the manufacturing of phosphate fertilizers. The property values for the concentrations of Al, As, Ca, Cd, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, V, and Zn of the material after digestion using microwave-assisted digestion were quantified with inductively coupled plasma optical emission spectrometry (ICP-OES). The homogeneity and stability were also determined as an In-House validated technique. Phosphorus mass fraction was determined by laser-induced breakdown spectroscopy. The accuracy of the measurement results was confirmed by analyzing the Certified phosphate rock and fertilizer Certified Reference Materials (NIST SRM 694 and SRM 695 respectively).

Aba & Ismaeel (2012) prepared an In-house Reference Material from a material that contained known amount of uranium ore mixed with marine sediment collected from Kuwait bay for the analysis of ^{226}Ra, ^{224}Th, ^{214}Pb, ^{214}Bi and ^{210}Pb radioisotopes. Also, Idris (2019) developed seven Reference Materials of soil and biological tissues for testing of macro, micro and trace elements (Ni, Pb, Zn, and Br) for environmental, toxicological, agronomic and nutritional purpose using wave dispersive X-ray fluorescence (WD-XRF). He used the between bottle homogeneity test method and found that the metals has relative standard deviation (RSD) >10% with the skewness and kurtosis revealing that the analytes in the materials are symmetrically distributed.

Conclusion

The importance of Quality Control in the determination of heavy metals concentration in soil cannot be overemphasized. The lack of the use of reference materials for quality control has resulted in the emergence of poor inter-laboratory precision in routine analysis of heavy metals in soil which could lead to poor decision, with negative effects on lives and the environment. The production of In-House reference material at a minimal cost is possible. All analytical laboratories are therefore encouraged to produce it for their use to enhance Quality control checks for a more reliable result.

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Table 1:Effect of land use on micro nutrient status (mg kg^{-1})

S/N	Land use	Mn	Fe	Cu	Zn	
1.	Wood lot plot	4.08	0.93	0.28	0.96	
2.	*Cajanus cajan* plot	3.33	0.95	0.35	0.66	
3.	Nursery plot	2.92	1.30	0.28	1.18	
4.	Vegetable plot	2.25	0.33	0.35	1.14	
5.	Cassava plot	2.55	0.53	0.68	0.73	
L.S.D		**1.23**	**0.05**	**0.06**	**0.07**	

Table 2: Effect of soil depth (cm) on soil micronutrients (mg kg^{-1})

Soil Depth (cm)	**Mn**	**Fe**	**Cu**	**Zn**
0-20	3.13	0.44	0.32	0.98
20-40	2.92	1.17	0.45	0.88
L.S.D	**0.78**	**0.03**	**0.04**	**0.05**

Table 3: Effects of land use and soil Depth (cm) on soil micronutrients (mg kg^{-1})

S/N	**Land use**	**soil depth (cm)**	**Mn**	**Fe**	**Cu**	**Zn**
1.	Wood lot plot	0-20	4.20	0.30	0.35	1.04
		20-40	3.95	1.55	0.20	0.87
2.	*Cajanus cajan* plot	0-20	3.85	0.35	0.05	0.76
		20-40	2.80	1.55	0.65	0.55
3.	Nursery plot	0-20	3.00	0.85	0.30	1.22
		20-40	2.85	1.75	0.25	1.13
4.	Vegetable plot	0-20	2.40	0.50	0.20	1.31
		20-40	2.10	0.15	0.50	0.96
5.	Cassava plot	0-20	2.20	0.20	0.70	0.57
		20-40	2.90	0.85	0.65	0.88
	L.S.D	**1.74**	**0.07**	**0.09**	**0.10**	

ASN 53rd Annual Conference Proceedings (Sub-Theme: Soil Conservation, Fertility and Water Mgt.)

Comparative Assessment of Soil Fertility and Carbon Content of Oil Palm and Palm Plantation in Isiala Mbano, Imo State, South Eastern Nigeria

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Abstract
This research work is the study on the comparative assessment of soil fertility and carbon content of oil palm and plantain plantation in IsialaMbano in Imo State, South Eastern Nigeria. A profile pit was dug in each plantation. Soil description was carried out according to FAO. Guidelines, soil samples were collected from each horizon, air dried and sieved for standard routine analysis. The soils were deep in depth and perfectly drained. Sand was dominant in yhe area and bulk density ranged from 1.33g/cm^{-3}- 1.47g/cm^{-3} in plantain plantation and 1.27g/cm^{-3}- 1.39g/cm^{-3} in oil palm plantation. The fertility levels of both soils were organic matter 0.89% in oil palm and 6.2 (mean) in plantain plantation. With these findings I therefore recommend that adequate attention should be given to soils in IsialaMbano in South Eastern Nigeria for the fertility of the soil to be highly ascertained in Agricultural activities and production.

Introduction
The fundamental basis of carbon (C) sequestration and its effect on global climate change and agriculture have become a major concern in recent years. Emissions of greenhouse gasses (water vapour) carbon dioxide (CO_2), meythane and nitrous oxides an s a result of human activities continue to alter the atmosphere in ways that are expected to affect change in climate. Anthropogenicactivities produce $C0_2$, which is the primary greenhouse gas that contributes to climate change to be released to the atmosphere at rates much faster than earth's natural processes can recycle. (Bauer, A and Black 1994). To help alleviate or possibly reverse the trend, a variety of means of enhancing natural sequestration, atmospheric CO_2 level are reduced as soil organic carbon (SOC) levels are increased. Among the three natural sinks for C (Ocean,, Forest and Soil), soils contain more C than is contained in vegetable and the atmosphere combined (Swift 2001). The SOC pool which forms the largest sink after sedimentary rocks and fossil deposits however is the most vulnerable to disturbance (Lal etal 2007) especially because of the competition between the various types of land uses. (Six et al. 2000) reported that tillage operations promote the loss of SOC through macro aggregate disruption and exposure of soil organic matter (SOM) to microbial decomposition. Also, the decomposition and alteration (mineralization and metabolization) of organic compound produces trace gasses which can be harmful to the global atmospheric cycle. However, the inner-Government panel on climate change (IPCC) recognized three main options for the mitigation of atmospheric CO_2 concentrations by the agricultural sector. (I) reduction of agriculture-related emissions (ii) creation and strengthening of C sinks in the soil and (iii) production of bio-fuels to replace fossil fuels (Batjes, 1998). Hence the need to evaluate the role of soil as one of the natural C sinks that secludes organic C as stable humus for enhancing soil fertility. The impact of C sequestration on greenhouse gases and agricultural sustainability has not been well elucidated at regional, national or global scales. Some available statistics are general based on extrapolation (Lal 2004). Reported that the rate of SOC sequestration in agricultural and restored ecosystems range from 0-150gkgCha-1 yr-1 in dry and warm regions and 100-1000kgC ha-1 yr-1 in humid and cool climates. He also estimated the total potential of C sequestration in world soils as 0.4-1.2 at C y-1, all of which were derived from national resource inventory.
The relevance of this study is to generate reliable information which is essential for developing techniques of soil/land management systems and for recommendation of agricultural practices that promotes C sequestration for sustainable agriculture leading to advancement of food security and consequently mitigate global warming.

Therefore, the main objective of the study was to assess the comparative soil fertility and carbon storage on oil palm and plantain plantations in Imo State. The specific objective was determining the soil physico-chemical properties of the soils studied.

Materials and Methods

Study Area: The study was conducted under three land use types in Mbano, Imo State South Eastern Nigeria which lies between Latitude 57° N and Longitude 7°17'E with an elevation of 150m above sea level which cover over 148km and over 1000 hectares of cultivable land with a population of 198,376 (NPC, 2006)

Geology and Geomorphology: The major parent material in the study area is the false bedded sand stone. The area has generally low land geomorphology and over 80m above sea level.

Pre- field Study: Reconnaissance visit was conducted on the study site to identify the areas for sampling after which a free survey sampling technique was adopted. A total of two profile pits were dug for the study. The samples were bulked, taken to the laboratory, air dried, sieved using 2mm sieve and used for determination of some physical and chemical properties following procedures outlined by FOA (2002).

Statistical Analysis: Data obtained were subjected to coefficient of variation which was used to estimate the degree of variability existing among soil properties in the study site.

Result and Discussion

Soil Physical Properties: The sand content of the assessment fertility ranged from 608.1-828.2gkg^{-1}, silt and clay content ranged from 40.0-80.1gkg^{-1} in plantain and 27.2-92.4gkg^{-1}. The parent material as well as climatic condition of the area studied played a significant role in the particle size distribution of the soil studies as sand was dominant. Both the oil palm and plantain has a sand texture which decreases throughout the horizons. The bulk density of the plantain plantation ranged from 1.33g/cm^{-3} – 1.47g/cm^{-3}, that of oil plantation ranged from 1.27g/cm^{-3} – 1.39g/cm^{-3}. The AP horizons were lower in bulk density followed by an increasing pattern in the sub soils horizon. Such pattern were attributed to high litter fall, high organic matter and microbial activities on the surface and better structural development in the sub soil horizons.

Chemical Properties of The Study Areas PH And TN: Result of the chemical properties of the study soils are shown in table 2, result shows that PH(H_2O) ranges from 6.18-6.08 in plantain and 5.60-6.01 in oil palm respectively, result shows that the sun reaction in water is therefore slightly acidic in all soils studied. This could be attributed to the parent materials of the area studied. Low acidity recorded in the soils could **also** be attributed to leaching of basic cations out of the soil solum and corresponding increase in H^+ of the exchange site (Silver *et al*., 1994). Total Nitrogen levels observed in all soils studied were moderate in all soils. Although, top soil recorded higher N values compared to subsequent horizons. The low N at the subsurface horizons may be attributed to the sandy texture of soils and resultant high mineralization and leaching through the profile (London 1991).

Effect of carbon storage on oil palm plantation and plantain plantation: Carbon stored in the soil depends fundamentally on the management practices of the soil. Table three shows that high carbon content was obtained in plantain plantation than in oil palm plantation which shows that excess root penetration in oil palm can reduce the carbon content of the soil unlike that of plantain plantation and it has nothing to do with each of the soil (Ahukaemere 2015).

Conclusion

This research was done to access different fertility and carbon content of different land use. The plantain plantation recorded higher SOC than the oil palm plantation soils. Therefore I recommend that growing of cover crops should be encouraged for improving of organic matter levels and hence soil quality.

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Table 1. Some Physical properties

Plantain Plantation Oil Palm	Sand (g/kg)	Silt (g/kg)	Clay (g/kg)	B.D (g/kg)
A	**828.2**	**90.1**	**92.4**	**1.39**
A	**703..1**	**58.2**	**78.2**	**1.47**
AB	**720.1**	**68.3**	**80.1**	**1.30**
AB	609.2	42.3	68.3	1.39
B+1	**608.1**	**72.5**	**76.3**	**1.27**
B+1	521.3	36.0	62.4	1.36
B+2	**626.3**	**40.0**	**27.3**	**1.28**
B+2	669.1	47.4	21.4	1.33

Table 2. Some chemical properties

Plantain Plantation	PH (H_20)	(TN/g/$cm^{2)}$
A	**6.08**	**0.361**
AB	**6.02**	**0.321**
B+1	**5.21**	**0.316**
B+2	**5.18**	**0.331**
Oil Palm (Ph)	**PH (H_20)**	**(TN/g/$cm^{2)}$**
A	6.01	0.361
AB	6.00	0.321
B+1	5.66	0.330
B+2	5.60	0.311

Table 3: Carbon storage

Plantain Plantation Oil Palm	(g/kg)	(g/kg)
A	**4.19**	
A		3.18
AB	**5.67**	
AB		3.08
B+1	**3.99**	
B+1		3.03
B+2	**3.89**	
B+2		3.00

ASN 53rd Annual Conference Proceedings (Sub-Theme: Soil Conservation, Fertility and Water Mgt.)

Conservation Agriculture as A Modern Global System of Soil Fertility Restoration and Management

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Abstract
Conservation Agriculture has the potential to protect soil and water while enhancing crop production and encouraging biodiversity. Conservation Agriculture is not a rigid, formalized system, but a flexible set of guiding principles based on: Minimal mechanical soil disturbance, mainly through direct seeding; Permanent soil cover, organic matter supply through the preservation of crop residues and cover crops; Crop rotation for bio-control and efficient use of the soil profile; and Minimal soil compaction. Application of Conservation Agriculture principles ought to be tailored to suit the wants and capabilities of the farm and farmer. On arable farms, the evidence suggests that wider implementation of Conservation Agriculture would significantly reduce soil erosion and improve soil structure and fertility, reduce diffuse pollution of water bodies and enhance biodiversity. Conservation Agriculture, if applied in the correct way, will bring significant benefits to farmers, the environment and society across the range of farm types and climatic regions of the globe.

Keywords: Conservation, Crop rotation, Environment, Soil, Fertility, Restoration, Management

Introduction

Agricultural soil is a precious and limited resource. Irreversible degradation of this resource implies not solely devastation the most plus of current farmers however additionally reducing the farming opportunities of future generations. Agricultural practices today seem to be shifting globally from conventional tillage to conservation agriculture (Lamhar, 2008). In all types of agriculture today, Soil fertility management and restoration emphasis are being placed on reducing land and water pollution, soil erosion, long-term dependency on external inputs, enhancing environmental management, improving water quality and water use efficiency, and reducing emissions of greenhouse gases through restricted use of fossil fuels. Conservation agriculture (CA) makes use of soil biological activity and cropping systems to reduce the excessive disturbance of the soil and to maintain the crop residues on the soil surface in order to reduce harm to the surroundings and supply organic matter and nutrients. It is based on four principles:

- Minimal mechanical soil disturbance (zero tillage), mainly through direct seeding;
- Permanent soil cover, organic matter supply through the preservation of crop residues and cover crops;
- Crop rotation for bio-control and efficient use of the soil profile;
- Minimal soil compaction.

Although the principles don't seem to be new (except for that of minimal disturbance to the soil), it is the fact that they are applied together in conservation agriculture that generates positive outcomes. The practice of minimal tillage, soil cover and crop rotation are merged for synergy and added value. In the past, farmers may have tried but neglected the use of cover crops or zero tillage due to problems associated with weed or yield declines. There is additionally a desire for improved weed management and rotations for bio-control of pests and diseases and nutrient uptake. Integration of the conservation agriculture principles provides a win-win scenario for each individual and also the surroundings, which has catalyzed successful improvement of soil fertility. Conservation agriculture is grounded on the principles of soil rejuvenation, envisioned to maximizing the use efficiency of agricultural inputs e.g. seed, nutrient, water, energy, and labour leading to higher profits to

the grower (Lamhar, 2008; Kassam and Friedrich, 2009). The goals of CA are to optimizing the crop productivity and farm income through maximum use of available resources and their effective recycling in the agroecosystem while arresting the adverse impacts on the environment (Jat *et al.,* 2012). It has been widely tested and demonstrated that long term application of CA resulted in better water quality, provided excellent soil erosion control, and lowered the greenhouse gases emissions associated with agriculture production (Kassam *et al.,* 2012). Long term adoption of conservation agricultural practices has been reported to extend the issue productivity and crop yields, enhanced agricultural sustainability, provided better income to the growers, ensure timeliness of cropping practices, reduction in plodding, and improved ecosystem services that results in various pattern of productivity, economic, social and environmental dividend from conservation agriculture technologies. Hence, there are need to adopt conservation agriculture as a modern global system of soil fertility restoration and management.

Conservation agriculture as a system for soil fertility restoration and management strategies

Being a biologically-based practice with an agro-ecological perspective, conservation agriculture does not focus on a single commodity or species. Instead, it addresses the complex interactions of several crops to particular local conditions capitalizing on the complex systems of interactions involved when managing soil systems productively and sustainably. Conservation agricultural systems would need to attend to the soil fertility restoration and management through the following strategies;

Effect of Conservation Agriculture on Management of Biomass Production and Biological Nitrogen Fixation

Conservation agricultural systems require higher levels of biomass production within the rotation to develop and maintain an adequate mulch cover, to raise soil organic matter level, to enhance soil biodiversity and their functions, to raise moisture and nutrient holding capacities, to enhance nutrient supplies, to enrich the soil with nitrogen in the case of legumes, and to protect the soil surface. Practices that enhance soil organic matter are built into CA principles and include one or more of the following, minimal or no-till; diversifying cropping systems; planting trees; mulching; using cover crops and green manures, using crop rotations; and using nitrogen-fixing crops.

Nitrogen is fixed from the atmosphere by all kinds of free-living organisms in undisturbed soils, and also by rhizobia in root nodules in legume crops as well as in herbaceous and woody legumes. Soil organisms including protozoa and nematodes in the root rhizosphere also fix atmospheric nitrogen, and so the nitrogen cycle has multiple pathways to restore nitrogen to the soil and supply to crops. For crop growth and for soil microorganisms to function, and for soil organic matter to build up, adequate nitrogen supply is needed. No-till and planted fallows and pastures in the rotation can preserve soil integrity and soil organic matter, and various herbaceous and tree legumes can make a contribution to maintaining a positive nitrogen balance for the cropping system (Boddey *et al.,* 2006). Equally, failure to compensate for any net nutrient outputs can lead to losses in soil organic matter and soil nutrient reserves in the short run, and to soil erosion and soil system degradation in the long term. Farmer and research experience have demonstrated the long-term benefits of a CA system. The major increase in soil organic matter content is assumed to be responsible for these benefits.

Effect of Conservation Agriculture on Managing Access to a Balanced Nutrient Supply

The lot of common notion concerning crop nutrition is predicted on maintaining overall quantities or concentrations of nutrients within the soil. At the practical level, this is reduced to a simple output input nutrient balance equation so that what is taken out by the crop is or must be replaced by application of nutrients from inorganic fertilizer or other sources. Invariably, this approach is combined with conventional soil tillage that reduces, over time, soil organic matter and porosity, and therefore also its water and nutrient holding capacity in addition to all the beneficial soil biological processes. Kinsey and Walters (2006) clearly shows from direct field experience across many years and many countries, that what is important is that not only is each element necessary individually, but a balance of all soil elements is necessary collectively. If there is too much of a given nutrient, it is going to tie up something else that is needed, e.g. too much potassium ties up boron, too much phosphorus ties up zinc, too much nitrogen ties up copper, and too much calcium could tie up all the other nutrients, depending on their availability. Also, imbalances in nutrients can lead to unbalanced plant metabolism making plants vulnerable to all kinds of pathogens as elaborated by Chaboussou (2004).

Conservation Agriculture in Management of Soil Biological Processes

Conservation agriculture practices (zero tillage, cover cropping, and organic matter) improves the soil structure which in turn enhances soil porosity, rate of water infiltration, and soil water holding capacity. These soil properties enhance the activities and population of the soil microorganisms thereby encouraging organic matter decomposition for the gradual release of nutrient element for fertility sustainability. Plants, rivers, and groundwater depend on water penetrating into the soil which is porous from the surface downwards.

Insufficiency of water for plants hinders the interacting functioning of the other components of soil productive capacity: biological, physical, and chemical. The rate of entry of water into and through and its movement within the soil is governed by soil's porosity, both micro and macro, which in turn is governed by the volume and inter-connectedness of pores able to transmit water. The volume and availability of water which plants can use are determined by the proportion of soil pores which can retain water against the force of gravity and yet can release that water in response to 'suction' exerted through roots as dictated by the plants' physiology and atmospheric demand. Water management in the soil is intrinsically linked to nutrient management. Conservation agriculture contributes markedly to the soil's capacity to capture and retain nutrient ions on organic complexes and provide a slow-release mechanism for their liberation back into the moisture in the soil. For this activity and its effects to be maintained, a sufficient supply of new organic matter needs always to be available as a source of energy and nutrients to the soil organisms and also improve soil fertility and crop productivity.

Effect of Conservation Agriculture on Management Soil Acidity

Soil pH is critical for several reasons. It has a major influence on the availability of elements, including primary nutrients like nitrogen, phosphorus and potassium, as well as secondary nutrients, micronutrients and potentially toxic elements like aluminum. Most soil microorganisms are sensitive to soil acidity, which has an influence on nutrient availability (especially nitrogen), soil organic matter and general soil health.

Conservational agricultural systems are based on building and breaking down organic matter to maintain soil health and productive capacity. As microorganisms decompose soil organic matter, organic acids are continuously being formed. If these acids are not neutralized by free bases, then soil acidity will increase. There are other reasons why soil can be acidic, due to leaching of basic cations by rainfall, or to the soil being formed from acid parent materials, or to biological nitrogen fixation. Where soils are acidic particularly in humid and sub-humid soils and may have toxic levels of aluminum, the effectiveness of broadcast lime application without incorporation has been long proven in CA systems, as lime moves into deeper soil layers, especially when applied in small quantities each year in combination with green manure cover crops (Derpsch, 2007). Experience Brazil shows that aluminum toxicity tends to disappear over time under CA systems.

Effect of Conservation Agriculture on Management of N P K in soil

Conservation agriculture practices, especially zero tillage, residue management, and crop rotation have a significant impact on nutrient distribution and transformation in soils (Galantini *et al.,* 2000), and the effects of these practices are related to soil organic content. Soil nitrogen (N) content usually affected by soil organic matter content, as the N cycle is inextricably linked to the carbon cycle (Bradford and Peterson, 2000). Intensive tillage reported to increases disruption of soil structure, making soil organic matter more accessible to soil microbes (Six *et al.,* 2002) and increasing mineralization of N from active and physically protected N pools (Christensen, 2001). The higher amount of stable micro-aggregates and increased levels of physical protection of carbon, as well as N, was reported under conservation agriculture (Lichter *et al.,* 2008). Zero tillage with residue retention over the long run can enhance the supplying power of soil that leads to higher soil available N as compared to conventional tillage. The composition (C:N, lignin, polyphenols and soluble C content) of residues will affect their decomposition as the CN ratio together with initial N, lignin, and polyphenols are one of the most often used criteria for residue quality and its rate of decomposition (Hadas *et al.,* 2004). Numerous studies also showed that phosphorus (P) stratification in soil under different tillage systems where zero tillage system associated with a higher concentration of P due to the preferential movement of P in the soil (Abdi *et al.,* 2014). Moreover, the shallower incorporation of crop residues and fertilizer P as well as small P losses due to water erosion under conservation agriculture leads to higher P contents in the surface soil. Piegholdt *et al.* (2013) also reported 15 % higher total P content in the topsoil (0-5 cm) of zero tillage plots as compared to conventional tillage due to larger P addition from the decomposition of residues retained on the soil surface. Likewise, higher P levels in zero tillage than in conventional tillage were reported by other researchers (Duiker and Beegle 2006). The higher values of available P under CA practices largely due to reduced mixing of the fertilizer P with the soil leads to lower P-fixation. This is a benefit when P is a limiting nutrient, but maybe a threat when P is an environmental problem because of the possibility of soluble P losses in runoff water (Duiker and Beegle, 2006). Franzluebbers *et al.* (1995) suggested that adoption of zero tillage leads to redistribution of P because of the direct result of the surface placement of crop residues that lead to accumulation of soil organic matter and microbial biomass near the surface. Conservation agriculture practices can conserve and increase the availability of K, near the soil surface where crop roots proliferate (Franzluebbers and Hons, 1996). Du Preez *et al.* (2001) observed increased levels of K in zero tillage compared to conventional tillage, but this effect declined with depth. Govaerts *et al.* (2007) found that the K concentration in both the 0-5 cm and 5-20 cm soil layers increased significantly with increasing residue retention under conservation agriculture. The recycling of the higher amount of crops residue of previously planted crops due to higher biomass yield lead to the addition of more nutrients.

Conclusions

Experience has shown that most things learned at university about fertilization and liming should be revised, and new concepts of fertility management for conservation agricultural systems need to be developed and applied. The main principle to keep in mind is that farmers should fertilize their soils rather than their crops." The benefits of CA system are rooted in soil health and function which should be managed by the farmers with a long-term perspective, and the evolving nutrient management practice should respond to the changing nutrient needs of the soil and cropping system as a whole. Ultimately, effective dissemination is important to enable the wider adoption of Conservation Agriculture to protect soil and water while enhancing biodiversity, productivity, and profitability.

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Effects of Municipal Solid Wastes on Soil Properties and Heavy Metal Concentration in Owerri, Southeastern Nigeria

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Abstract
This study investigated the effects of heavy metal pollution from municipal solid wastes on soil properties in Owerri, Southeastern Nigeria. Soil sampling was conducted using a survey technique involving random stratified sampling at three sites measuring 10×25 meters each. Each site was then subdivided into fifteen (15) equal sub-areas which served as sampling spots at depths of 0-15cm (topsoil) and 15-30cm (subsoil). Fifteen representative topsoil and fifteen representative subsoil samples (5kg each) were collected from fifteen spots at 5m intervals on each site. Ninety soil samples were obtained from the three sites comprising of Avu and Aba road dumpsites, and the control site. The samples were prepared for laboratory analyses by air drying and sieving using 2mm aperture and the levels of accumulation of heavy metals (Pb, Cd, Cr, Zn, and Ni) were determined. Atomic Absorption Spectrophotometer was used to discover that concentrations of heavy metals were higher at the abandoned dumpsite than at the new dumpsite; and least values were found at the control site. The vertical distribution pattern of heavy metals in the soil was in the following order Zn>Ni>Cr>Pb>Cu>Cd. Decomposed and corroded municipal wastes contributed significantly ($p \leq 0.05$) to the metal concentrations in dump soil samples. Bulk density at control site was 7.6% higher than bulk density at Avu dumpsite and 1.8% higher than bulk density at Aba road dumpsite. The influence of municipal solid wastes on soil properties is as a result of the dumping of inorganic waste materials at the dumpsites. Sorting of wastes at source should therefore be enforced to minimize heavy metal load of soils at dumpsites. Land filling of hazardous wastes should be adhered to so as to reduce environmental pollution and/or soil degradation

Keywords: Heavy metals, Pollution, Municipal, Solid Wastes, Soil Properties

Introduction

Soil is a primary recipient of waste products used in modern society (Brady and Weil, 1999). It is also a recipient of heavy metals due to anthropogenic activities (Alloway, 1995; He et al., 2004 and Javier and Rafael, 2005). Heavy metals are referred to as metals with densities greater than a certain value usually 5 or 6g/cm^3 (Wild, 2001). Indiscriminate dumping of wastes leads to excess accumulation of heavy metals such as cadmium, chromium, nickel, lead, mercury and arsenic (Onweremadu et al., 2007). Pollution and toxicity problems are commonly associated with heavy metals. These heavy metals, at certain levels of bioaccumulation, become toxic to the living components of the ecosystem. The inorganic pollutants from metals, metal salts, mineral substances, solid particulate matter and other synthetic chemical compounds and their by-products pollute dump soils (Alloway, 1996). Municipal solid waste includes wastes generated from residential, commercial, industrial, institutional, construction, demolition process, and municipal services. The absorption of heavy metals into the soil constrains the use of these waste materials as soil amendments (Warman and Rodd, 1999). However, the impact of heavy metals on soil properties depends on source, as metal forms from anthropogenic activities are environmentally unstable, more soluble and bioavailable than natural sources (Naidu, et al., 1997). The way these wastes are collected, handled, stored and disposed of constitutes hazards to the environment especially to the soil and to public health. Therefore, the aim of this study was to evaluate the effect of heavy metal pollution from municipal solid wastes and recommend ways of ameliorating the hazardous effects on our environment.

Materials and Methods

The study sites are in Imo state bounded by longitudes 7º 00'E and 7º 10'E and latitude 5º 25'N and 5º 30'N. Imo state lies within the humid tropics with mean daily temperatures of 27ºC. The average annual rainfall is

about 2400mm. Imo state has rainforest vegetation characterized by multiple tree species. In terms of geology and geomorphology, the predominant parent material underlying Imo state from which most of the soils are formed is the Coastal Plain Sands popularly known as "Acid Sands" (Orajaka, 1975). It is also called Benin formation. Farming is a major economic activity even in urban areas where patches of subsistence farms are found. The soil fertility is maintained by fallow, whose length is fast reducing due to high demographic pressure (Onweremadu, 1994). Soil samples were collected from two dumpsites: Avu abandoned dumpsite along Owerri-Port-Harcourt express road and the currently in use Aba road dumpsite along Owerri-Aba road. Samples were also collected from a fallow land which served as the control and it is located along Avu-Nekede road. Soil sampling was conducted using a survey technique involving random stratified sampling. A 10×25m area was taken from the dump head. The area was then subdivided into fifteen (15) equal sub-areas which served as sampling spots at depths of 0-15cm (topsoil) and 15-30cm (subsoil). Fifteen representative topsoil and fifteen representative subsoil samples (5kg each) were collected from fifteen spots at 5m intervals on each site. The first 15(topsoil) samples labeled (Av1 to Av15) and second 15(subsoil) samples labeled (Av16 to Av30) were taken from the Avu abandoned dumpsite. In the same way, 15 samples labeled (Ab1 to Ab15) for topsoil and 15 samples labeled (Ab16 to Ab30) for subsoil were collected from the Aba road dumpsite. Also, 15 samples labeled (C1 to C15) for topsoil and another 15 samples labeled (C16 to C30) for subsoil were collected from the fallow land along Avu-Nekede road and used as control. Soil samples were prepared for laboratory analyses by air-drying and sieving using 2-mm aperture. The experiment was a factorial experiment arranged in randomized complete block design. There were three treatments which comprised of location, soil depth and sampling distance. The locations were: Avu and Aba road dumpsites, and a control site; soil depths were: 0-15cm and 15-30cm while sampling distance was at intervals of 5m at 5 spots in 3-straight lines. Ninety soil samples were collected, thirty samples from each sampling location which served as replicates. Laboratory analyses were conducted for particle size distribution by the hydrometer method (Gee and Or, 2002), bulk density by core method (Grossman and Reinsch, 2002), total porosity was calculated from values of bulk density (Vomocil, 1965), moisture content by gravimetric method (Gardener,1965), soil pH by the use of pH meter (Hendershot, et al.,1993), total carbon by Walkley and Black wet oxidation method (Nelson and Sommers, 1982), organic matter by multiplying total carbon by factor of 1.724 (Van Bemmelen's correction factor), total nitrogen by micro-kjeldahl method (Bremner and Malvaney, 1982), available phosphorus according to the procedure of Olsen and Sommers (1982), exchangeable bases by ammonium acetate leaching and exchangeable acidity by titration (Thomas, 1982). Digestion of soil samples for heavy metals was carried out with a mixture of concentrated $HClO_4$ and HNO_3 at a ratio of 2:1 and heavy metals were extracted using 0.5M HCl (Lacatusu, 2000). The heavy metal concentrations in the supernatant were determined using Atomic Absorption Spectrophotometer (Buck 205 model). Data collected were subjected to analysis of variance, and means were compared using Least Significant Difference (LSD) at 5% confidence level (Little and Hills, 1978; Wahua, 1999). Correlation and regression analyses were also carried out, and simple coefficient of determinant was obtained.

Results and Discussion

Soil Properties: Soil samples obtained at Avu dumpsite comprised of 84.60% sand, 9.53% clay and 5.87% silt for the surface soil and 86.0% sand, 10.67% clay and 3.33% silt for the subsoil. The particle size analyses of Aba road dumpsite were 85.98% sand, 11.06% clay and 2.93% silt for topsoil and 85.14% sand, 12.53% clay and 2.33% silt for subsoil. The same soil texture was obtained at the Control site comprising of sand, clay and silt at the proportion of 84.28%, 11.99% and 3.72% respectively for topsoil and 81.32%, 15.20% and 3.46% respectively for subsoil (Table 1). Texturally, the soils are loamy sand. The characteristic sandiness of the soil could be attributed to the nature of parent material (Coastal Plain Sands) from which the soil is formed, coupled with aggressive tropical climate. Sandiness of these soils suggests easy leaching of heavy metals and nutrients through the pedosphere to groundwater. Lower bulk density and higher percentage porosity values were recorded from the polluted soils and this could be attributed to higher organic matter content when compared with the unpolluted soils. Waste contaminated soils have relatively higher organic matter content compared with that of non-waste contaminated soils (Wild, 1994). Consequently, higher values of total carbon were recorded from contaminated soils. Soil available phosphorus was also higher in contaminated soils when compared with uncontaminated samples. Higher pH values in the contaminated soils are traceable to low exchangeable acidity of the contaminated soils. It has been established that there is significant negative correlation between soil pH and exchangeable acidity (Landon, 1991; Brady and Weil, 1999; Singer and Munns, 1999). Also, higher values of exchangeable bases in the contaminated soils are traceable to higher pH values; hence higher values of effective cation exchange capacity in the contaminated soils. Gravimetric moisture content was higher in the contaminated soils when compared with uncontaminated soils. Guidi and Hall, 1984, stated that available moisture content increased with increasing amount of wastes in the soil.

Heavy Metals Concentration and Pollution: The maximum allowable limits of heavy metals in irrigation water, soils and vegetables have been established by standard regulatory bodies such as World Health

Organization (WHO), Food and Agricultural Organization (FAO) and Ewers U, Standard Guidelines in Europe as shown in Table 2. It has been affirmed that the value of zinc (978 mg/kg) obtained from the surface soils of Avu dumpsite (Table 3) is 106% more than its maximum permissible level in soil. Therefore, the surface soils of Avu dumpsite are polluted by zinc. Other sites also recorded high values of zinc but they are not toxic to the soil. The sites reveal that the closer the dump head the greater the percentage of heavy metals concentration. The value of cadmium (0.62 mg/kg) at 5m away from the dump head of Avu dumpsite is 194% greater than its value (0.01 mg/kg) at 15m away (Table 3). Greater percentages of heavy metals have been recorded at the surface soils of the dumpsites. A peculiar example is the concentration of Cd at the surface soil (0.25 mg/kg) of Avu dumpsite which has 113% greater than its concentration at the subsurface soil (0.07 mg/kg) (Fig.1). This may be attributed to the complete accumulation and decomposition of materials containing Cd at the surface soils of Avu dumpsite. According to Page et al., (1987), within soil profile, Cd tends to be present at higher concentrations in the surface horizon which is partly a reflection of the inputs from various sources. The control site also contained heavy metals; by and large, the decomposed dumpsite (i.e. Avu dumpsite) contained greater values of heavy metals than the partially decomposed dumpsite (Aba road dumpsite) and the control site.

Relationships between Heavy Metals and Some Soil Properties: The relationships between heavy metals and soil properties are shown on Table 4. Total nitrogen had the highest influence on the studied heavy metals in the pedosphere, indicating significant ($p \leq 0.05$) relationships with Pb ($r^2=0.270$), Cr ($r^2=0.283$) and Zn ($r^2=0.385$) while chromium showed the highest influence on soil parameters indicating significant ($p \leq 0.05$) relationships with soil pH ($r^2=0.376$), ECEC ($r^2=0.355$), total nitrogen, TN ($r^2=0.283$), and Av.P ($r^2=0.285$). This implies that as chromium concentration in soils increases, these soil parameters decrease. The coefficient of determination obtained when bulk density correlated with lead in this study ($r^2=0.038$, $p=0.05$) corroborated with the findings of Onweremadu (2008). There was non-significant relationship between moisture content and heavy metals. Poor relationship was also established between heavy metals and bulk density as well as porosity. One would expect a great influence of bulk density and/or porosity on heavy metals but such may have been masked by other soil properties. Site locations showed significant ($p \leq 0.05$) relationships with Cu and Zn and very highly significant ($p \leq 0.001$) relationships with Pb, Cr, Soil pH, Organic matter, Clay, TN, Av.P and ECEC. This means that these heavy metals and soil parameters had noticeable effect on the dumpsites and possibly on the control site as well. Bulk density and porosity had effect on spatial variability thus they showed very highly significant ($p \leq 0.001$) relationship with distance and depth.

Conclusions and Recommendations

The study revealed high level of accumulated metal ions in the top soil of the dumpsites. Amongst the studied heavy metals, zinc was the outstanding metal that caused soil pollution precisely in the top soil of Avu dumpsite. Long term dumping of municipal wastes influences soil properties (such as bulk density) and productivity at the abandoned sites. However, the sites may be used for farming activities provided that the ecotoxological risks associated with their usage are continuously assessed and controlled. Phytoremediation needs to be adopted to control the effect of heavy metals on soil that may be used for farming. Sedum alfredii Hance (dong nan jing tian) a perennial herb in Asia; identified as a new zinc hyper accumulating plant species has been recommended for remediation. However, the level of heavy metals can be reasonably reduced if solid wastes are sorted and the inorganic parts are recycled. Therefore, to minimize heavy metal load of soils in dumpsites following waste decomposition and/or corrosion, sorting of wastes at source among the general public in towns and cities is suggested in addition to the provision of an enabling statutory regulation on waste management in the country. Those wastes that pose greater health hazards should be properly land-filled to reduce environmental pollution and/or soil degradation. This will in effect reduce the concentration of heavy metals in the soil.

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Table 1: Mean values of soil properties

	Sand %	Clay %	Silt %	Textural class	pH (H_2O)	Av.P (mg/kg)	BD (g/cm□)	PD (g/cm□)	GMC %	TP %	TN %	TC %	OM %	EA (meq/ 100g soil)	EB (meq/ 100g soil)	ECEC (meq/ 100g soil)
Avu Dumpsite																
Surface Soil	84.60	9.53	5.87	LS	7.91	33.60	1.34	2.58	9.97	48.12	0.07	1.75	2.97	0.67	29.12	29.80
Subsoil	86.00	10.67	3.33	LS	8.27	27.02	1.72	2.58	9.23	33.15	0.04	0.96	1.66	0.58	19.59	20.18
Aba Road Dumpsite																
Surface soil	85.98	11.06	2.93	LS	8.31	36.54	1.47	2.58	9.96	39.66	0.04	0.68	1.17	0.51	14.48	14.98
Subsoil	85.14	12.53	2.33	LS	7.05	31.78	1.79	2.60	9.49	35.75	0.03	0.43	0.74	0.62	4.80	5.42
Control Site																
Surface soil	84.28	11.99	3.72	LS	6.05	14.00	1.49	2.64	9.89	43.26	0.03	1.02	1.75	1.35	1.01	2.36
Subsoil	81.32	15.20	3.46	LS	5.98	11.69	1.82	2.63	8.78	30.56	0.02	0.69	1.18	0.66	0.84	1.48

LS = Loamy Sand

Table 2. Maximum Allowable Limits of Heavy Metals in irrigation water, soils and vegetables (µg/g).

Chemical Elements	*Maximum Permissible Level in Irrigation Water (µg/ml)*	Maximum Permissible Level in Soils (µg/g)	Maximum Permissible Level in Vegetables (µg/g)
As	0.10	20	–
Cd	0.01	3	0.10
Co	0.05	50	50.00
Cr	0.55	100	–
Cu	0.017	100	73.00
Fe	*0.50*	50,000	425.00
Mn	0.20	2,000	500.00
Ni	1.40	50	67.00
Pb	0.065	100	0.30
Se	0.02	10	–
Zn	0.20	300	100

Source: U. Ewers, Standards, Guidelines and Legislature Regulations Concerning Metals and Their Compounds. In: Metals and Their Compounds in Environment Merian. E. (Ed), VCH, Weinheim, New York, Basel, Cambridge, 199, 1687-711.

Table 3. Heavy Metal Concentration (mg/kg) in the surface soils of Avu Dumpsite (0-15cm)

Soil samples in meters away from dump head (M)	Samples	Pb	Cd	Cu	Cr	Zn	Ni
5	Av1	0.60	0.16	0.01	1.69	63.43	0.85
10	Av2	0.35	0.10	0.01	1.23	58.43	0.44
15	Av3	0.85	0.22	0.02	2.15	68.43	1.26
20	Av4	0.66	0.51	0.53	2.22	973.01	1.88
25	Av5	0.71	0.40	0.42	2.12	968.01	1.38
5	Av6	0.61	0.62	0.64	2.32	978.01	2.38
10	Av7	0.47	0.01	0.18	1.08	29.82	0.71
15	Av8	0.54	0.01	0.11	1.02	22.62	0.63
20	Av9	0.40	0.01	0.25	1.14	37.02	0.79
25	Av10	0.19	0.48	0.42	1.11	40.91	1.26
5	Av11	0.14	0.43	0.38	1.07	40.61	1.15
10	Av12	0.24	0.53	0.46	1.15	41.21	1.37
15	Av13	<0.01	0.07	0.29	0.78	10.81	7.28
20	Av14	0.01	0.03	0.25	0.76	10.31	7.06
25	Av15	0.02	0.11	0.33	0.80	11.31	7.50

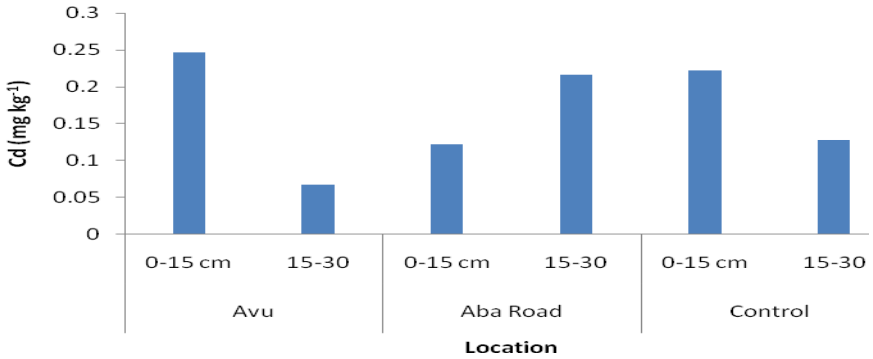

Fig. 1: Distribution of Cadmium (Cd) with depth at various locations.

Table 4: Correlation coefficients of soil properties and heavy metals in the study sites.

Property	Pb	Cd	Cu	Cr	Zn	Ni
pH	0.131^{NS}	0.152^{NS}	0.189^{NS}	0.613*	0.246^{NS}	0.036^{NS}
Clay	0.252^{NS}	0.028^{NS}	0.120^{NS}	0.438^{NS}	0.400^{NS}	0.067^{NS}
OM	0.506*	0.065^{NS}	0.061^{NS}	0.391^{NS}	0.522*	0.206^{NS}
ECEC	0.442^{NS}	0.054^{NS}	0.185^{NS}	0.596*	0.454*	0.190^{NS}
TN	0.519*	0.142^{NS}	0.033^{NS}	0.532*	0.621*	0.039^{NS}
Av.P	0.130^{NS}	0.005^{NS}	0.159^{NS}	0.534*	0.314^{NS}	0.119^{NS}
BD	0.196^{NS}	0.177^{NS}	0.084^{NS}	0.118^{NS}	0.222^{NS}	0.231^{NS}
Porosity	0.173^{NS}	0.210^{NS}	0.103^{NS}	0.069^{NS}	0.187^{NS}	0.249^{NS}
MC	0.076^{NS}	0.075^{NS}	0.001^{NS}	0.112^{NS}	0.051^{NS}	0.113^{NS}

NS: Not significant @ p = 0.05;*: Significant @ p≤ 0.05.

ASN 53rd Annual Conference Proceedings (Sub-Theme: Soil Conservation, Fertility and Water Mgt.)

Evaluating Hydraulic Properties of Soils: A Management Strategy towards Fighting the 21st Century Flood Disaster

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Abstract
Infiltration is the key to soil water conservation and management. The ability of the soil to act as a sponge in order to cut down the rising cases of loss of lives and property with associated impact due to flood disaster lies on its infiltration capacity. The study evaluated the strength of soils of University of Abuja Flood meadows to absorb hydrological shock as flood. Outcome of the study revealed that dry land of University of Abuja flood meadow is able to absorbed reasonable quantity of water as flood, with coefficient of variability value of 12% for the hydraulic conductivity of the site while bulk density of the area was found to be 2.30 g cm^{-3} and Porosity 8%. The study shows that the side has a weak hydrological potential in regards to adsorbing and transporting of the water down the soil profile, hence the area should be put to vegetation cover to reduce the flooding impact alongside an advance drainage system in the area

Keywords: Hydrology, Soil infiltration, Water flux, Vegetation, Water

Introduction

Humankind has experienced several challenges including flooding. Flood is defined as a very large amount of water that has overflowed from a source as a river, a pond or a broken pipe to cover a previously dried area (Oku and Aiyelari, 2011). With the increasing frequency in the impact of climate change the manse of flood has been severe here-and-there, especially in the tropical regions (IPCC, 2000). Flooding occurs when soil and vegetation of an area is unable to absorb the volume water released through rainfall or water bodies overflow (Hume, 1993, Ogban et al., 2000). Damages caused by flood have been reported globally to include: crop loss, destruction of lives and properties, distortion of economic activities and the psychological trauma associated with the disaster. Flooding is one of the major environmental crises one has to contend with within the 21st century. Floods are among the most devastating natural disaster in the world, claiming more lives and causingmore property damage than any other natural phenomena (UNFCCC, 2009). Flood events have been frequent during the last decade, causing loss of lives, extensive damage to properties, including houses, destruction of transport infrastructures, agricultural land degradation, breakdown in educational system and food production (NEMA, 2008).

The number of reported flood disaster in Nigeria has been huge, especially during the rains. The Federal Capital Territory of Nigeria have experienced it own share of flood cases, with several cases of loss of human (NEMA, 2008) lives.Against the increasing disaster due to flood, this study aimed at evaluating the infiltration behavior (hydrological property) of soils in-other to prepare against flood shock.

Materials and methods

The Study Area

University of Abuja lies at Latitude Abuja is 8°.95' 43'' and Longitude is 7°.07'47''. University of Abuja is located in sub-locality of Gwagwalada a times can record extreme maximum temperature which varies from 37°C in the south west (Bida) to about 30°C in the north-east (Jos) (NIMET, 2009). The two distinct season

within the zone are rainy and dry season. The parent material of the area is characterized by the presence of stones, gravel with ironstone sand to loamy texture.

Study site Description

The study was conducted at the University of Abuja flood-meadow at a topo-sequence. These flood-meadow are among the major source of dry season vegetable crops for the local farmers.

Site Selection and Soil Sampling

Flood meadows areas were surveyed along the Giri River, and the following were selected:

1. Cultivated flood meadow with code (CM)
2. Dried Land (Control) with code (C)
3. Fallowed flood meadow with code (FM)

Experimental Procedures

Two replicate infiltration runs was carried out in all the site selected. The experimental set up is presented in Figure 2.

Infiltration Experimentation and Modelling

The double ring infiltrometer method was used (Anderson and Ingram, 1989). Infiltration model as proposed by Philip (1957) and Kostiakov (1932) were used.

Estimation of Infiltration Characteristics

Optimal values of the parameters of the two models were estimated using regression module of the GENSTAT package. To estimate the Kostiakov model parameters, the cumulative infiltration and time data were subjected to a non-linear regression analysis ($z = kt^a$) to find the parameters k and a. Using the final infiltration rate, the cumulative infiltration and time data were subjected to a non- linear regression analysis ($z - ft = kt^a$) to determine parameters k and a for the modified Kostiakov model. The Philip's model parameters were estimated by subjecting the cumulative infiltration and time data to a linear regression analysis ($zt^{-0.5} = S + At^{0.5}$) to find the parameters S and A.

Fitting infiltration models

The infiltration data were analyzed according to the model of Kostiakov (1932) using Equation 1 and Philip (1957) using Equation 2 as these two models are frequently used in the humid forest zone to characterize infiltration:

$I = C\ t\ \alpha$

(1)

$I = St^{1/2} + At$

(2)

where

I = Cumulative infiltration (cm)

C = Initial infiltration (cm min-1 or cm h-1)

α = Index of sorptivity of the soil reflecting the decline of the infiltration rate

S = Sorptivity and embodies the

Results and discussion

Analysis as presented in Table 1 shows infiltration behavior on the flood meadows. The trend of infiltration characteristics differed with the different land use with slope positions. Infiltration of water into the soil along the topo sequence was lowest on the fallowed area of t6he meadow, presenting a view that soil bulk density could enhance high infiltration rate in the soils, this view was also made in the work of Oku and Aiyelari. The flooding treatments exerted significant influence on the investigated hydrological property of the different landuse. The flux in hydrological strength of the soils occurred at an unequal rate, this could be attributed to the different topo-unit of the sites, this view confirms the study of Wu et al (1997)

Conclusion and recommendation

The outcome of the study shows that the soils of the Flood meadows has low ability to infiltrate water into the soil profile. And for the area to be safe in the case of six hours continuous ponding from rain, irrigation or water overflow then evaluation of resident is advice. It could also be said that since the dried land (control

site) indicated a highest water flux, it means that if proper drainage system in perform in the area then cases of water overflow in the area could be minimized if not eradicated. Outcome of this investigation shows that the fallowed land absorbed water than the cultivated land, and thus it could be concluded that for disaster due to flood to be minimized in the area such area with similar characteristics should be left on their natural vegetation or planted to grass like vetiver for cover.

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Fig. 1: Extrapolated map of Abuja from the map of Nigeria

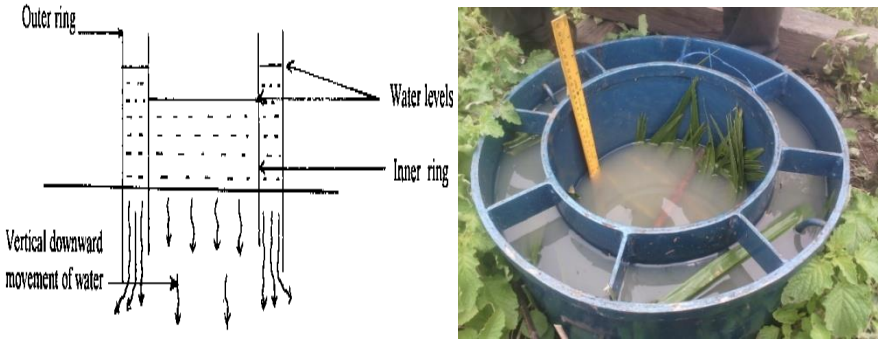

Figure 2: Infiltration experiment with soil infiltrometer

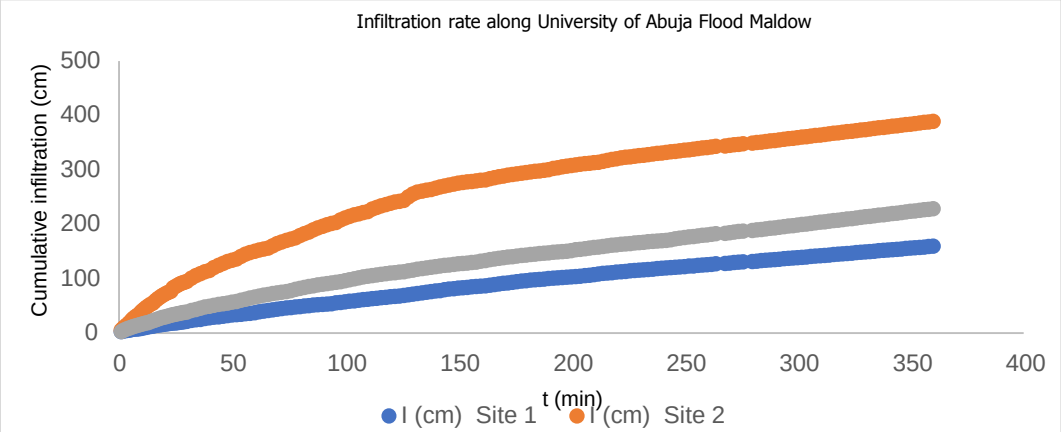

Figure 3: Hydraulic Behavior of the meadow soils of University of Abuja

Table 1: Infiltration behavior along Flood meadows
X=mean, SD = Standard deviation, CV = coefficient of variability, SE = Standard error, A = absorptivity, S = transmissivity, C = Index of initial infiltration,ά = index of soil stability, R^2 = Correlation Model, r=correlation coefficient

Table 1: Infiltration behavior along Flood meadows

Site	Hydraulic Conductivity	Model	R^2	Bulk density (gcm^{-3})	Porosity (%)
CM	0.346	0.432+12.009	0.9909	2.16	18
C	0.46	0.9717+86.05	0.9177	2.30	8
FM	0.387	0.588+27.78	0.9797	1.83	31

ASN 53rd Annual Conference Proceedings (Sub-Theme: Soil Conservation, Fertility and Water Mgt.)

Evaluation of different Fertilizer Recommendation Approaches for Cocoa Seedling Growth in Nigeria under Greenhouse Conditions

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Abstract
Greenhouse experiment was conducted at CRIN Headquarters, Ibadan using soil samples collected under cocoa plantation at CRIN Headquarters, Ibadan and two of the CRIN substations- Owena in Ondo state and Ajassor in Cross River state to determine the effect of different fertilizer recommendation approaches on the growth of cocoa seedlings. Four fertilizer recommendation approaches (soil test, fertilizer factor, blanket and control) were used. Fertilizer usage significantly enhanced seedling growth better than control in the soils of the three locations. Fertilizer applied using fertilizer factor approach significantly increased cocoa leaves production better than other fertilizer treatments in all the three locations. The cocoa seedling growth as influenced by fertilizer recommendation approaches were in the order of fertilizer factor > soil test > blanket> control. The study recommends that farmers should avoid blanket fertilizer usage and embrace fertilizer recommendation based on soil test or fertilizer factor approaches.

Introduction

Soils under cocoa plantations in Nigeria are depleted of some vital nutrient elements. This is largely due to "nutrient mining" as a result of annual pod harvest without replacement of the nutrients in form of fertilizer application. Harvest of 1000kg dry cocoa beans removes 20kg N, 4kg P and 10kg K from the soil (Omotoso 1975). In Nigeria, where pod husk are taken out of the farm, the amount of K removed is five fold. In spite of the advantages of fertilizer usage, many cocoa farmers do not still use fertilizer on their cocoa (Ogunlade et.al 2009, Agbeniyi et.al 2010). Fertilizer use by a few farmers is based on blanket recommendation which does not result in desired increase in crop growth and yield. Fertilizer recommendation based on the results of soil testing also has its own limitation because it does not consider the amount of nutrient fixed or immobilized in the soil. Okeya 1975, Ayodele and Agboola 1981 explored the use of fertilizer factor as an approach to fertilizer recommendation which is the amount of nutrient required to raise the soil nutrient by one unit to take care of the immobilized nutrient. With this, provision was made for the fixed nutrient in order to meet the actual crop need. The objectives of this study are to evaluate fertilizer factor and soil test values as fertilizer recommendation approaches for cocoa seedlings and compare these approaches with blanket fertilizer recommendation in order to suggest the best for optimum growth and yield of the test crop.

Materials and Methods

Soil samples were collected under cocoa plantations at CRIN Headquarters, Ibadan, CRIN substations at Owena in Ondo State and Ajassor in Cross River State. The soil samples from each of the locations were bulked together separately to ensure homogenous mixture, air dried and sieved through 2mm sieve. Soil samples collected at CRIN substations were brought to Ibadan, CRIN headquarters for the green house experiment. Black plastic pots (5 litres size) were used for the experiment. 5kg sieved soil was weighed into each of the pots used. Four treatments comprising three fertilizer recommendation approaches (i) Fertilizer factor (FF) (ii) soil test value using critical level of nutrient (ST) (iii) Blanket (BT) and (iv)control (CT)

without fertilizer application were replicated four times and arranged in a randomized design. There were sixteen experimental units (16 pots) for each location. In the fertilizer factor treatment, fertilizer calculations were made with reference to critical values of the nutrient elements. The fertilizer factor of the element in question was used to multiply the difference between the critical and soil test levels. The fertilizer factors for P and K previously determined for those soils by Ogunlade et.al (2011) were used. The blanket fertilizer recommendation of 10kg N/ha 5kg P_{205}/ha and 10kg K/ha calculated in proportion to 5kg of soil were applied to each pot of soil. Cocoa beans were planted into each pot and thinned to one seedling per pot two weeks after emergence. Fertilizers were applied one month after planting. Watering was done three times in a week. Growth parameters – plant height, stem diameter and number of leaves were measured monthly. The dry matter yield of the leaves, stem and root of cocoa seedlings were also determined six months after planting when the experiment was terminated.

Results and Discussion

The nitrogen, phosphorus and potassium contents of the soils as shown in Table 1 were below the critical levels for cocoa as reported by Egbe et al 1989, hence the need for fertilizer application.

Ibadan location: Fertilizer factor significantly improved cocoa seedling height better than blanket and control at 2, 4 and 6 months after planting in Ibadan. Cocoa seedlings under fertilizer factor consistently had higher seedling height than soil test. This is expected since blanket approach did not consider the nutrient in the native soil before application. The blanket recommendation may either cause nutrient imbalance or nutrient antagonism. The findings in this study was similar to the reports of Fashina et.al (2006) and (Shitu and Fasina., 2004). Stem diameter of cocoa seedlings under fertilizer factor treatment were significantly higher than other treatments at 2, 4 and 6 months after planting (Table 3). Cocoa seedlings under soil test treatment had significantly higher stem diameter than control. Cocoa seedlings under fertilizer factor produced significantly more leaves than other treatments at 2, 4 and 6 months after planting in Ibadan (Table 4). Soil test treatment resulted in significantly higher number of leaves than blanket and control treatments at 2, 4 and 6 MAP in Ibadan (Table 4). Fertilizer factor significantly improved the leaf and stem dry matter yield of cocoa seedlings better than blanket and control treatments. The root dry matter yield of cocoa seedlings was significantly higher under fertilizer factor than control treatment (Table 5). There was no significance difference between the dry matter yield of cocoa seedlings under fertilizer factor and soil test treatments, however fertilizer factor consistently increased dry matter yield better than soil test treatment. (Table 5)

Owena location: At Owena, fertilizer factor significantly improved cocoa seedling height better than soil test, blanket and control treatments at 4 and 6 months after planting (Table 6). All the fertilizer treatments significantly improved cocoa seedling height better than blanket and control treatments at 2 and 4 months after planting in Owena. Fertilizer factor significantly enhanced cocoa seedling stem diameter higher than other treatments at six months after planting (Table 7). All the fertilizer treatments significantly improved cocoa seedling stem diameter better than control at 2, 4 and 6 MAP (Table 7).

Leaves production by cocoa seedlings were significantly enhanced by fertilizer factor better than other treatment at 2 and 4 months after planting (Table 8). At six months after planting, fertilizer factor and soil test treatments significant enhanced number of leaves better than blanket and control treatment (Table 8). This was similar to the findings of Wessel 1980, who reported that fertilizer application based on soil test can increase the yield of cocoa to about 50% of the usual yield. At Owena, fertilizer factor significantly enhanced leaf, stem and root dry matter yield higher than other treatments (Table 9).

Ajassor Location: At Ajassor, fertilizer factor significantly gave higher seedling height at 2, 4 and 6 months compared with other treatments. At six months after planting, soil test treatment significantly enhanced plant height higher than Blanket and control treatments. (Table 10). Fertilizer factor treatment gave significantly higher cocoa seedlings stem diameter at 2, 4 and 6 months after planting than the other treatments (Table 11). The production of leaves in cocoa seedlings was significantly higher in soil treated with fertilizer factor approach than other treatments. (Table 12). Leaf, stem and root dry matter yield of cocoa seedlings were higher under fertilizer factor than other treatments. Fertilizer factor and soil test approaches significantly increased root dry matter yield than blanket and control treatment (Table 13).

Conclusion

Greenhouse experiment was conducted at CRIN Headquarters, Ibadan and two of the CRIN substations- Owena in Ondo state and Ajassor in Cross River state to determine the effect of different fertilizer recommendation approaches on the growth of cocoa seedlings. Four fertilizer recommendation approaches (soil test, fertilizer factor, blanket and control) were used. The study revealed that fractional recovery using fertilizer factor approach showed significant superiority over blanket fertilizer recommendation and control treatments. The superior performance of the test crop (cocoa) under fertilizer factor treatment might be due to the provision made for the nutrient elements that were fixed up, which was not considered under soil test and blanket fertilizer recommendation approaches. The nutrient imbalance caused by blanket fertilizer recommendation could also be partly responsible for inferior performance of test crop under blanket treatment. This study further confirmed that fertilizer recommendation based on fractional recovery using fertilizer factor and soil test approaches are the best for determining the adequate amount of nutrients needed to replenish the soil in order to meet the crop needs. The study recommends that farmers should avoid blanket fertilizer usage and embrace fertilizer recommendation based on soil test or fertilizer factor approach.

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Table 1. Initial physical and chemical properties of the soils at the three locations

Soil Properties	Ibadan	Owena	Ajassor
pH	6	5.8	5.05
Organic Carbon(g/kg)	10.10	11.3	15.02
Total N(g/kg)	0.77	0.85	0.49
Available P(mg/kg)	4.11	5.23	8.40
Exch. K(cmol/kg)	0.22	0.18	0.11
Exch. Ca(cmol/kg)	4.45	4.19	0.48
Exch.Mg(cmol/kg)	1.23	1.42	0.41
Exch. Na(cmol/kg)	0.13	0.11	0.13
Exch.acidity(cmol/kg)	0.73	0.82	2.20
Zn(mg/kg)	5.56	6.55	8.99
Cu(mg/kg)	6.40	5.37	66.18
Mn(mg/kg)	18.90	13.80	186.22
Fe(mg/kg)	5.83	6.62	120.84
Sand(g/kg)	600	720	672

Silt(g/kg)	240	180	154
Clay(g/kg)	160	100	174
Texture	Sandy loam	Sandy loam	Clayey loam

Table 2: Effect of fertilizer treatments on cocoa seedlings height at Ibadan

Fertilizer Treatments	Height		
	2 MAP	4 MAP	6 MAP
Fertilizer Factor (FF)	45.7 a	72.3 a	83.1 a
Soil Test (ST)	41.8 ab	67.8 ab	75.3 ab
Blanket (BT)	36.6 bc	63.8 b	72.5 b
Control (CT)	32.5 c	62.5 b	69.3 b

MAP: Months after planting

Table 3. Effects of fertilizer treatments on cocoa seedlings stem diameter at Ibadan

Fertilizer Treatments	Stem Diameter		
	2 MAP	4 MAP	6 MAP
Fertilizer Factor (FF)	0.89 a	1.31 a	1.51 a
Soil Test (ST)	0.76 b	1.19 b	1.41 b
Blanket (BT)	0.70 b	1.02 c	1.35 bc
Control (CT)	0.63 c	0.93 d	1.30 c

Table 4: Effects of fertilizer treatments on number of leaves of cocoa seedlings at Ibadan

Fertilizer Treatments	Number of Leaves		
	2 MAP	4 MAP	6 MAP
Fertilizer Factor (FF)	20 a	41 a	53 a
Soil Test (ST)	17 b	36 b	40 b
Blanket (BT)	16 bc	29 c	37 bc
Control (CT)	15 c	25 c	34 c

Table 5: Effect of fertilizer treatments on leaf, stem and root dry matter yield of cocoa seedlings at Ibadan, six months after planting

Fertilizer Treatments	Leaf dry matter yield	Stem dry matter yield	Root dry matter yield
Fertilizer Factor (FF)	19.0 a	18.0 a	11.8 a
Soil Test (ST)	17.3 ab	17.3 ab	11.1 ab
Blanket (BT)	16.4 bc	15.3 b	10.6 ab
Control (CT)	14.8 c	14.4 b	9.7 b

Table 6: Response of cocoa seedlings height to different fertilizer treatments at Owena

Fertilizer Treatments	Height		
	2 MAP	4 MAP	6 MAP
Fertilizer Factor (FF)	35.8 a	60.8 a	82.8 a
Soil Test (ST)	32.5 ab	51.8 b	69.5 b
Blanket (BT)	29.0 b	49.0 b	64.0 bc
Control (CT)	23.6 c	43.0 c	59.3 c

Table 7: Response of cocoa seedlings stem diameter to different fertilizer treatments at Owena

Fertilizer Treatments	Stem Diameter		
2 MAP	4 MAP	6 MAP	
Fertilizer Factor (FF)	0.76 a	0.98 a	1.50 a
Soil Test (ST)	0.71 ab	0.91 ab	1.21 b
Blanket (BT)	0.66 b	0.81 b	1.13 b
Control (CT)	0.56 c	0.68 c	0.99 c

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Table 8: Response of number of leaves of cocoa seedlings to different fertilizer treatments at Owena

Fertilizer Treatments	Number of Leaves	
2 MAP	4 MAP	6 MAP

Fertilizer Factor (FF)	17.0 a	35.0 a	42.0 a
Soil Test (ST)	13.0 b	30.0 b	39.0 a
	13.0 b	25.0 c	32.0 b
Blanket (BT)			
Control (CT)	12.0 b	21.0 d	28.0 b

Table 9: Response of cocoa seedlings leaf, stem and root dry matter yield to fertilizer treatments at Owena, six months after planting

Fertilizer Treatments	Leaf dry matter yield	Stem dry matter yield	Root dry matter yield
Fertilizer Factor (FF)	21.6 a	17.1 a	12.3 a
Soil Test (ST)	17.9 b	13.9 b	10.6 b
Blanket (BT)	16.0 bc	13.7 b	9.7 b
Control (CT)	14.6 c	13.0 b	9.3 b

Table 10: Influence of fertilizer treatments on cocoa seedlings height at Ajassor

Fertilizer Treatments	Height		
	2 MAP	4 MAP	6 MAP
Fertilizer Factor (FF)	37.8 a	59.5a	83.1 a
Soil Test (ST)	32.9 b	52.5 b	72.5 b
Blanket (BT)	32.4 b	51.5 b	67.8 c
Control (CT)	29.4 c	47.0 c	61.3 d

Table 11: Influence of fertilizer treatments on the stem diameter of cocoa seedlings at Ajassor

Fertilizer Treatments	Stem Diameter		
	2 MAP	4 MAP	6 MAP
Fertilizer Factor (FF)	0.87 a	1.19 a	1.55 a
Soil Test (ST)	0.74 b	1.01 b	1.35 b
Blanket (BT)	0.66 c	0.93 b	1.24 c
Control (CT)	0.59 d	0.81 c	1.15 d

Table 12: Influence of fertilizer treatments on the number of leaves of cocoa seedlings at Ajassor

Fertilizer Treatments	Number of Leaves		
	2 MAP	4 MAP	6 MAP
Fertilizer Factor (FF)	15 a	36 a	42 a
Soil Test (ST)	13 b	28 b	35 b
Blanket (BT)	12 b	24 b	32 b
Control (CT)	10 bc	18 c	26 c

Table 13: Influence of fertilizer treatments on the cocoa seedlings leaf, stem and root dry matter yield at Ajassor, six months after planting.

Fertilizer Treatments	Leaf dry matter yield	Stem dry matter yield	Root dry matter yield
Fertilizer Factor (FF)	21.9 a	16.9 a	13.9 a
Soil Test (ST)	19.0 a	15.6 a	12.4 a
Blanket (BT)	18.3 ab	16.3 a	10.6 b
Control (CT)	15.8 c	13.2 ab	9.5 b

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Evaluation of Water Quality Index of River Musa, Bida, Nigeria for Drinking purpose

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Abstract
Rivers are fresh water sources that are essential for the betterment of human well being. The objective of this study was to evaluate selected physicochemical parameters (Total dissolved oxygen (TDS), pH, ammonia (NH^4), Sodium, Calcium, Magnesium and four heavy metals (Fe, Pb, Cu and Mn)) of river Musa to reveal the detailed water quality data of the river for easy understanding of the water quality index for drinking purpose. To achieve the objective, Canadian Council Water Quality index (CCWQI) was applied on the analytical results of the parameters to obtain a single value that was used to rank the river at each of the sampling location. The Annual average water quality index at five locations are (40.9, 42, 40, 39.1 and 37.5). The results showed that the five stations investigated can be ranked as poor. The implication is that the river failed Drinking Water Quality Index and therefore not suitable for drinking water purpose.

Introduction
Water is one of the most important inputs needed for the plant growth in agricultural production. In irrigation, natural sources of fresh water are rivers, dams, lakes, streams and ground water.
Rivers in any water shed play an important role for moving of industrial, municipal and agricultural wastes. The economic value of every water decreases due to the presence of pollutants which affects human health and other aquatic forms of life (James, 2008). Although human beings benefit immensely from water for farming, drinking, fishing and even for transportation and yet are the major contributors of water pollution through agricultural wastes dumping, industrial dumping, mining wastes dumping etc. Hence, it is imperative to assess river pollution and have reliable information on the quality for different purpose.
Nasir *et al.,* (2012) reported that Surface water as an important component of the environment is the major recipient of the pollutants originating from various sources from manmade activities and also from naturally occurring activities within our environment. The authors reported that the high susceptibility of surface water to pollution was due to its easy accessibility of natural and anthropogenic activities from its surrounding.
Sources of rivers water pollution have been classified into a point and non point sources. According to John (2017) A point source is a single identifiable localized source of water pollution, example of point source are sewage treatment plants, factory effluents etc while non-point sources are identified as diffuse sources of pollution which cannot be traced back to a particular location due to pollution originating from a wide variety of human activities on the land and natural processes, example use of fertilizer and pesticide in food production. In the 1970s Canada and the USA undertook a program of non- point source identification and control for the Great Lakes Basin. Research has shown that, the majority of the common fresh water sources in Nigeria are polluted, leading to serious outbreak diseases and sudden deaths. Research conducted by Umeh *et al.,* (2004) cited by Aboyeji (2013) in his work showed that 48% of the people in Katsina-Ala local

government of Benue state, Nigeria are affected by urinary schitosomiasais, because of increase in water pollution index.

Aboyeji (2013) noted that the causes of water pollution in some Nigeria communities are industrial based water pollution, agricultural water pollution, oil spill based water pollution and domestic water pollution.

River Musa is a major river of economic, agricultural and environmental significance in the town. The river water is used by the people of Bida and its environs for different activities (irrigation, fishing and household usage). The objective of the study was to evaluate seasonal variation of some selected physicochemical properties of River Musa and determines its water quality status for drinking purpose using Canadian Council of Ministers of Environment (CCME) water quality Index.

Methodology

River Musa is the major river of economic purposes that flows in Bida town, Niger state. This river flows in south-east, which covers an area of about 17.5 $km^2$and lies 6^0 00' -6^0 15'E; 9^0 2' -9^0 5' N (NIGIC, 2018). Bida has annual rainfall ranges from 1000mm to 1200mm with a marked rainy season from April to October. Average annual air temperature is 27^oC. The river is use for economic and agricultural importance in the town .It served the people of Bida and its environs for different activities (irrigation, fishing and household usage).

Sampling and Analytical Technique

Samples were measured from five locations (Edokota, Musa mini Bridge, Bida/Minna bridge, Cirriko and Army Barrack bridge) for $_PH$, Magnesium, Calcium, Ammonia, Total dissolve solids, Sodium and heavy metals (Iron, Lead, Manganese and Cupper). The $_PH$ was measured using pH meter. Total dissolved solid, Ammonia, Calcium, Magnesium and Sodium were determined using standard methods recommended by the American Public Health Association (APHA, 1995). Heavy metals were determined using Atomic Absorption Spectrometer (AAS). The heavy metals of water samples were evaluated by digesting water samples using concentrated nitric acid HNO_3 and concentration of Iron (Fe), Cupper (Cu), Lead (Pb) and Manganese (Mn) were measured with S series atomic absorption spectrophotometer (AAS).

Method of Samples Collection

Samples collection was carried out by the use of plastic bottle containers which was washed. Bottles were being properly rinsed with the river water at location points and were properly labelled in reference to sample points. Samples were filtered with whatman paper to remove particles before analysed. Samples were collected at five (5) different locations representing the main sources of pollutants. Detention time of samples was 45 minutes between the sampled sites and laboratory.

Water Quality Index Evaluation

Water Quality Indices make use of a 'single value' for the expression of overall water quality of a particular source at a certain period of time on the basis of some water quality variables (Yogendra and Puttaiah, 2008). The Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) was used as a statistical technique for the work due to its simplicity and ability to simplify Drinking Water Quality (DWQ) data without compromising the technical integrity of the data (Hassen *et al.,* 2005). The results of these parameters were compared with World Health Organisation standard (WHO). The WQI determination using CCME consist of three factors; Scope F_1, Frequency F_2 and Amplitude F_3 (John, 2009). These factors were calculated for five locations.

The Index compares the compliance of the observed data to a water quality standard or objective to give a score ranging from 0, indicating worst quality to 100 signifying the best quality. The Index is helpful in monitoring water quality change at a specific location over a stated period of time and also in comparing directly among stations that employed the same variables and objectives. The index was used to quantify for the station or among the stations the number of parameters that exceed or fall below the standards.

Results and Discussions

Water Quality Index for the five locations along the river was calculated for rainy and for a year using selected physicochemical parameters listed in Table 3.1. The values of the various scopes (F_1), frequencies (F_2), and amplitudes (F_3), with their respective water quality index are presented in Table 3.2. During the rainy season, the water quality index values of the river at the stations i.e Edokota location, Musa min bridge station, Bida/Minna station, Cirriko station and Army Barrack station were 43, 46.3, 46.1, 43.9 and 37.7. The values showed that the water can be ranked as poor at Edokota, Cirriko and Army barrack station, and poor at the

other stations. During the dry season, the water quality index values were relatively lower; however, respective ranks remained poor for all the stations. The average annual index values (Table 3.3) of the river Musa (which range from 37.5 to 42.0) shows that the water quality for drinking purposes at the all locations can be ranked poor. The poor ranking of the river could be attributed to different types of pollutants entering the river due to various anthropogenic activities at those stations. Pollutants such as domestic sewage, runoff water from agricultural lands and abattoir wastes near the banks of the river may be responsible for the poor water quality of the river. The poor water quality rating observed is determined by the analytical results of the physiochemical parameters as shown in (Table 3.1) chosen for WQI calculation. The results of pH values obtained are presented in table 3.1. The pH average values of five stations during rainy season range from 5.00-5.97. These values fallen below the WHO standard (6.5-8.4). This could be attributed to agricultural runoff from lands within the locations. During the dry season, high averages values range from (5.3-7.57) were observed in the five stations compared to rainy season data. The pH value of the river at the Edokota station has the highest average value of (7.57) and slightly alkaline compared to other stations. This could be attributed to hardness of water as a result of concentration of calcium carbonates during dry season which are mostly $CaCO_3$ from rocks, sulphate and nitrite of calcium and magnesium. The variations of pH between Edokota Bridge and other sampling stations during rainy and dry seasons were statistically insignificant at 5% (between upstream and downstream). During the rainy season the TDS average values range from 9.35 to 148.74 mg/l with the highest value recorded at Ciriko station (148.74 mg/l) and are within the WHO standard (0-500 mg/l). During the dry season the TDS average values of the river musa at the five stations ranges from 11.10 -104.34 mg/l. The variations of total dissolved solids between Edokota and other sampling stations during both seasons season were statistically significant at 5% level. During rainy season Na average values of all locations range from 7.00 – 23.49 mg/l and all fallen within the WHO standard (0-200 mg/l)) with highest value obtained at Edokota station. During the dry season the recorded Na average values for the studied sites ranged from 1.13-15.83 mg/l, with the highest value recorded at Ciriko station. The variations of Sodium between Edokota and other sampling stations for both rainy and dry seasons were statistically significant at 5% level.

During rainy season the average values of Ca at all sampling points ranged from 1.27-6.55 mg/l and are fallen within the permissible limit recommended by WHO (0-200 mg/l). During the dry season, the average calcium concentration at all sampling points ranged from 10.95-24.32 mg/l with the highest value recorded at Cirriko station (24.32 mg/l). The variations of Calcium between Edokota and other sampling stations for both seasons were statistically insignificant at 5% level. The average magnesium values at all sampling points during wet season ranged from 1.13-8.23 mg/l and are within the WHO threshold (0-150 mg/l). During the dry season, average magnesium values at all sampling points ranged from 14.92-30.82 mg/l which were within the threshold. During dry season average values of Mg were higher than the rainy season values because of high level of concentration of water hardness. The variations of magnesium between Edokota and other sampling stations for both seasons were statistically insignificant at 5% level. During rainy season the average iron values at all sampling points ranged from 0.534-0.995 mg/l with highest value recorded at Army barrack station (0.995) which were above the WHO standard (0-0.3 mg/l). During the dry season, the iron average values of the river musa at the five stations above the permissible limit. The values ranged from 0.34-0.46 mg/l. The variations of Iron between Edokota and other sampling stations during wet season were statistically significant at 5% level. During the dry season the variations of Iron between Edokota and other sampling stations were statistically insignificant at 5% level.

During wet season the average values of manganese at all sampling points ranged from 0.25-0.68 mg/l. The Mn average values of the river musa at the five stations are above the permissible limit recommended by WHO (0-0.1). During the dry season the average Manganese values at all sampling points ranged from 0.34-0.45 mg/l and have above the permissible limit recommended by WHO. The high values of manganese at all stations for both rainy and dry seasons could be attributed to the disposing of industrial waste into the river from mechanic villages near the stations. The variations of Mn between Edokota and other sampling stations were statistically insignificant at 5% level for the two seasons. During rainy season the average values of ammonia at all sampling points ranged from 0.96-1.21 mg/l and all above the permissible limit recommended by WHO (0-0.2 mg/l). During the dry season, the average ammonia concentration at all sampling points ranged from 4.40-6.97 mg/l with the highest value recorded at Army barracak station (6.97 mg/l). The higher concentration of ammonia during both seasons could be attributed to discharging of domestic and abattoir

wastes into the river along the river banks. The variations of ammonia between Edokota and other sampling stations for both seasons were statistically insignificant at 5% level.

During rainy season the average values of Cu at all sampling points ranged from 0.30-0.58 mg/l and all below the permissible limit recommended by WHO (0-1.0 mg/l). During the dry season, the average Cu concentration at all sampling points ranged from 0.33-0.78 mg/l. The variations of Cu between Edokota and other sampling stations during wet season was statistically insignificant at 5% level and during the dry season the variation of Cu between the all sampled points was statistically significant at all points. During rainy season the average values of Lead at all sampling points ranged from 0.15-0.38 mg/l and all above the permissible limit recommended by WHO (0-0.01mg/l). During the dry season, the average Pb concentration at all sampling points ranged from 0.42-0.51 mg/l. The high level of the lead during the both seasons at all stations could be attributed to disposing of industrial waste into the river from mechanic villages near the stations and as well as dissolved of lead metal products disposing into the river. The variations of Lead between Edokota and other sampling stations during both seasons were statistical insignificant at 5% level.

Conclusion

Seasonal variation of selected physicochemical properties of River Musa was assessed and the river water quality index was determined using CCME water quality Index. The result of study revealed that the river is not suitable for drinking purpose. More so, the study showed that application of Water Quality Index is a useful tool in assessing the quality of river for drinking purpose in the study area.

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Table 1. WHO set of established Standard

Parameters	WHO
pH	6.5-8.5
Lead	0.01
Manganese	0.1
Sodium	200
Cupper	1.0
Iron	0.3
Ammonia	0.2

Magnesium	150
Total Dissolve solids	500
Calcium	200

Source: WHO water drinking standard (2019)

Table 2. Canadian water quality index ranking, values and description

Ranking	CWQI Values	Description of the Ranks
Excellent	95-100	Water quality satisfies all criteria for drinking purpose
Good	80-94.4	Water quality rarely disagree criteria for drinking purpose
Fair	65-79.9	Water quality sometimes disagree criteria for drinking purpose
Marginal	45-64.9	Water quality often violates criteria for drinking purpose
Poor	0-44	Water quality do not satisfies any criteria for drinking purpose

Source: CCME (2005)

The WQI determination using CCME consist of three factors; Scope F_1, Frequency F_2 and Amplitude F_3. These factors were calculated for five locations.

Scope (F_1) represents those water quality parameters with objectives which were tested during the time period for the index calculation.

$F_1 = \left(\frac{Number\ of\ failed\ variables}{Total\ number\ of\ variables}\right)$ X100..... (1.1)

Frequency (F_2) represents the percentage of individual tests that do not meet the Objectives ('failed tests'):

$F_2 = \left(\frac{Number\ of\ failed\ test}{Total\ number\ of\ test}\right)$ X100..... (1.2)

3. Amplitude (F_3)

This is a measure of amplitude. This was calculated in three steps:

Step 1a: Calculation of Excursion in which failed tests greater than objective involves the use of formula below

Excursions = $\left(\frac{Failed\ Test\ Value}{Objective}\right)$ -1..... (1.3a)

Step1b: Calculation of Excursion in which failed tests less than objective was calculated as below

Excursions = $\left(\frac{Objective}{Failed\ Test\ Value}\right)$ -1..... (1.3a)

Step 2: Calculation of Normalized Sum of Excursions (nse)

Nse = $\frac{\sum_{k=1}^{n}(Ecursions)}{Total\ number\ of\ tests}$..... (1.4)

Step 3: Calculation of Amplitude (F3).

$F_3 = \left(\frac{nse}{0.01nse+0.01}\right)$ .....(1.5)

The CWQI was finally evaluated as:

WQI=100- $\left(\frac{\sqrt{F_1^2+F_2^2+F_3^2}}{1.732}\right)$ ..... **(**1.6)

Statistical analysis is done for the parameters studied for correlation with SPSS (21.0 software) package.

Table 3. Descriptive statistics of the wet season of water quality parameters of River Musa

LOCATION	Ca(mg/l)	Mg (mg/l)	Na(mg/)	N-NH3mg/ l	Fe(mg/l)	Mn (mg/l)	Cu mg/ L	pH	Pb mg/ L	TDS(Mg/l)
Sample pt 1										
Mean	1.38	2.47	23.49	0.98	0.534	0.257	0.30	5.97	0.23	16.92
Minimum	0.64	2.30	22.90	0.88	0.478	0.043	0.20	4.90	0.15	13.32
Max	2.08	2.70	23.86	1.11	0.589	0.471	0.35	8.00	0.40	19.98
SD	0.72	0.21	0.51	0.12	0.078	0.303	0.09	1.76	0.14	3.36
Sample pt 2										
Mean	6.55	1.13	20.95	1.15	0.594	0.411	0.32	5.63	0.15	9.35

Minimum	1.76	0.30	18.76	0.90	0.590	0.329	0.05	5.10	0.15	6.66
Max	16.03	1.70	23.30	1.65	0.598	0.493	0.45	6.60	0.16	13.32
SD	8.21	0.74	2.27	0.43	0.006	0.116	0.23	0.84	0.00	3.51
Sample pt 3										
Mean	1.27	3.43	20.20	1.21	0.645	0.482	0.43	5.50	0.15	12.99
Minimum	0.96	2.50	17.80	0.95	0.589	0.471	0.40	5.00	0.15	6.66
Max	1.64	4.40	24.10	1.69	0.700	0.493	0.45	6.50	0.15	18.98
SD	0.35	0.95	3.41	0.42	0.078	0.016	0.03	0.87	0.00	6.17
Sample pt4										
Mean	1.92	8.23	17.87	1.06	0.702	0.686	0.58	5.07	0.15	148.74
Minimum	1.68	6.90	9.90	1.00	0.700	0.471	0.50	4.80	0.15	113.22
Max	2.31	10.20	22.90	1.16	0.703	0.900	0.75	5.50	0.15	179.82
SD	0.33	1.74	6.98	0.09	0.002	0.303	0.14	0.38	0.00	33.52
Sample pt 5										
Mean	1.72	4.23	7.00	0.96	0.995	0.451	0.41	5.00	0.38	42.18
Minimum	0.80	2.90	2.20	0.91	0.589	0.430	0.35	4.70	0.15	13.32
Max	2.20	6.20	9.90	1.04	1.400	0.471	0.44	5.20	0.50	59.94
SD	0.80	1.74	4.19	0.07	0.573	0.029	0.05	0.26	0.20	25.21
WHO standard	0-200	0-150	0-200	0-0.2	0-0.3	0-0.1	0-1.0	6-8.5	0.01	0-500

Table 4. Quality index for Wet and Dry season

	Wet season				Dry Season			
Scope	F_1	F_2	F_3	WQI	F_1	F_2	F_3	WQI
Station								
Edokota	50	40	74.1	43.4	50	42.5	84.1	38.4
Musa	50	40	67.3	46.3	60	37.5	81.0	37.8
Bida/Minna	50	40	67.8	46.1	60	47.5	85.0	33.9
Cirriko	50	42.5	71.5	43.9	50	47.5	90.0	34.3
Army Barrack	50	45	84.3	37.7	50	40	87.4	37.4

Table 5. Average Annual WQI and the Ranking

Station	Average Annual WQI	Ranking
Edokota	40.9	Poor
Musa	42	Poor
Bida/Minna	40	Poor
Cirrriko	39.1	Poor
Army Barrack	37.5	Poor

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Forms and Profile Distribution of Phosphorus along a Toposequence of Amaeke Ibeku Soils, Umuahia, Abia State, Nigeria

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Abstract
The forms and distribution of phosphorus (P) in soil along a toposequence at Amaeke Ibeku in Umuahia North LGA of Abia State of Nigeria were investigated in 2017. Five pedons representing crest, upper slope, middle slope, lower slope and valley bottom were assessed. A total 25 auger soil samples were collected from 0-20, 20-40, 40-60, 60-80 and 80-100cm depth at five sampling units along the toposequence. The samples were analyzed for various forms of P and other physical and chemical properties. Soil P varied widely the distribution of forms of P at different depths along the toposequence was not uniform. The site has a very low (< 9%) organic P (P_o) contribution to the total P (TP). The occluded P constituted 66-74% to TP and total inorganic P (TP_I) forms in the soils respectively. The occluded P and Fe-P occupied over 90 % of the TP_I. Active P_I constituted 19 and 22 % TP. Ca-P and Al-P were lower (< 8 %) than other forms of P in the soils, while Al-P was low in lower horizons of the soil. The relative abundance of various forms of P_I were as follows: Ca-P < Al-P < Fe-P < Occluded P. Correlation coefficient indicated that the P forms are closely related while multiple correlation analysis revealed that TP correlated positively ($p < 0.05$) with Al-P, Fe-P and Occluded P. P_O had a significant negative correlation with sand (r = -0.56*), Available P (-0.41*) and positive relationship ($p < 0.05$) (r = 0.62*) with silt. Occluded P correlated negatively with Mg (r = -0.40*) and positively with Al-P, Fe-P, Ca-P, and total P. Al-P correlated positively with Fe-P, Ca-P, Occluded P and total P. Fe-P correlated positively with Al-P, Ca-P, Occluded P and total P. Soil P_E is above the critical level of 15mg kg^{-1}. The present study indicates that the TP status and other P forms is not influenced by the topography of the study soil.

Keywords: Phosphorus, P-Forms, P-Distribution, Toposequence, Soil-P

Introduction

Phosphorus is one of the most limiting nutrient elements in the tropics (Ahn, 1993). Low availability of phosphorus in tropical soils is attributed to the forms of soil phosphorus and the high content of oxides of iron (Fe) and aluminum that is associated with phosphorus fixation (Mokwuonye *et al.,* 2002). The complexity of behavior of phosphorus in soils and the factors influencing phosphorus has been reviewed (Ubah, 2000; Ohaeri and Eshett 2011; Ohaeri, 2012; Ohaeri., 2016; Nwosu *et al.,* 2018). In Nigeria, studies have evaluated the effect of toposequence on soil properties (Oluwatosin *et al.,* 2001; Nwosu *et al*., 2018), but there are varied findings from such studies. Ogban *et al.,* (1999) deduced that nutrient status and soil properties of a location are related to topography of the area. Osodeke *et al.* (2006) observed a wide variation in phosphorus distribution along a toposequence in south eastern Nigeria. They found that total phosphorus was highest at the upper slope and lowest at the middle slope. Amaeke Ibeku is situated in an undulating terrain with varying toposequence. Farmers cultivate on these slopes. Like most tropic soils, the soils of Ibeku

are associated with low soil nutrients (NPK) which have negative impact on crop yield. Considering the varying topography of the area and the impact of rainfall (erosion) on soil nutrients, it is therefore imperative to investigate the effect of slope positions of Ibeku soils on some soil chemical properties, so as to provide detailed information about the fertility status of the area. The findings from this study will help make appropriate recommendation on the type and amount of fertilizer to apply and suggest soil management practices that is best suited for the area to ensure sustainable crop production. Thus, the objectives of the present study were to: (i) determine some chemical and physical properties of soils (ii) evaluate the effect of toposequence on the forms of phosphorus distribution and (iii) determine the relationship between these various forms of P.

Materials and Methods

This study was conducted along a toposequence in Ibeku Amaeke, which is located on latitude5^{o} 32′ N and longitude 7^{0} 33′ E) in Umuahia North Local Government Area of Abia State, South-Eastern Nigeria (The site was geo-referenced using handheld Global Positioning System (GPS) Receiver (Garmin Ltd Kansas, USA). The toposequence of the study area was delineated into five units viz Crest, Upper slope, Middle slope, Lower slope and Valley bottom. Soil samples were collected at 0-20, 20-40, 40-60, 60-80, and 80-100 cm depth using soil auger and were air-dried for 3 days at room temperature. One portion of the air-dried soil samples was gently crushed with a wooden roller and passed through a 2-mm sieve for chemical analysis while the other portion was crushed with a mortar and passed through 0.5-mm sieve for organic carbon analysis. Particle size distribution was determined by hydrometer method using sodium heaxmetaphosphate (calgon) as dispersing agent as outlined by Gee and Or (2002). Soil pH was determined in water using Bechman's pH meter in a soil to water ratio of 1:2.5 (Thomas, 1996). Organic carbon was determined by the dichromate wet oxidation method (Nelson and Sommers, 1996). Exchangeable bases (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}) were extracted with 1 N ammonium acetate (NH_4OAc) at pH 7.0. Calcium and Mg in the extracts were determined by titration (Jackson, 1958) while Na^{+} and K^{+} were determined with flame photometer. Exchangeable hydrogen and Al^{3+} were determined by the method outlined by Mclean (1982). Effective cation exchange capacity (ECEC) was calculated as the sum of total exchangeable bases and total exchangeable acidity (Tan, 1996). Percentage base saturation was calculated as outlined by Coleman and Thomas (1967). Total phosphorus was determined by perchloric acid digestion method (Jackson, 1958) and organic P was estimated by the difference between 13 M HCl extractable inorganic P, before and after ignition (Leg and Black, 1955). Inorganic P was fractionated by Chang and Jackson (1957) method as modified by Peterson and Corey (1966). Available P was extracted using Bray II method (Bray and Kurtz, 1945), Phosphorus concentration in the soil extracting solution was determined colorimetrically using ascorbic acid method (Kuo, 1996) on a spectrophotometer set to 880 nm.

Data analysis: Data on soil P forms and soil properties were analyzed using statistical computer package of GenStat Release computer (2017). Pearson correlation and regression analyses were used to determine the relationship among the various P forms and the relationship between P and other soil properties. The significance of the relationship was tested at $P < 0.05$.

Results and Discussion

The results of physicochemical of the soils are given in Tables 1 and 2. Silt/clay ratios (Table 1) ranged from 0.11-3.00 with their means less than unity (0.53), indicating that the soils are old and highly weathered (Essoka and Esu, 2005). Soil is acidic and has a pH range of 4.2 – 5.8

Total phosphorus: Total P varied widely and ranged from 138.92 - 1631.34 mg kg^{-1} with a mean of 976.21 mg kg^{-1} from 0-100 cm depth across the toposequence (Table 2). These values are comparable with the values reported by Ohaeri and Eshett (2011) in Ajata Ibeku soils, derived from Shale. The high total P in Amaeke Ibeku soils is due to the high phosphate content of the parent rock from which the soils of Southeastern Nigeria were formed (Akamigbo and Asadu, 1983). The highest (1041.12 mg kg^{-1}) and lowest (815.58 mg kg^{-1}) total P content were obtained at upper slope and middle slopes. The result obtained showed that the distribution total P across the toposequence is not uniform (Udo and Dambo, 1979; Ohaeri and Eshett, 2011 and Ohaeri, 2012). The highest (1632 mg kg^{-1}) total P was obtained at lower slope at 20-40 cm depth while the lowest (139. mg kg^{-1}) total P was obtained at valley bottom at 80-100cm depth. Total P is higher in the location but available P is overall low (Table 3). The low available P associated with Ibeku soil will hamper plant growth since plants require P for adequate growth and development. There was no

significant correlation between total P and the selected soil properties. This result is similar to the findings of Nwosu *et al*. (2018) on their study on Amaoba soil but is contrary to the reports of Osodeke and Kamalu (1992), Ohaeri and Eshett (2011) and Ohaeri (2012). Total P had significant ($p<0.05$) positive correlation with inorganic P forms (Al-P, Fe-P and occluded P) except Ca-P, organic P and available P (Table 5). The correlation coefficient result indicates that the P forms are closely related. These findings agree with that of Azeez *et al.* (2013) who reported that all the P forms are closely related.

Organic P : Organic P contents of the soils varied widely across the toposequence. Similar to total P, the distribution of organic P along the toposequence is irregular. The upper slope (80-100 cm depth) had the lowest (12.09 mg kg^{-1}) Organic P (Table 3) while the middle slope (20-40 cm depth) had highest (273.39 mg kg^{-1}) Organic P. The Organic P values constitute 11.7% of the soil total P content. The Organic P values are comparable with the values of 34 - 339 mg kg^{-1} and 30 to 900 mg kg^{-1}reported by Loganathan and Sutton (1987) for soils in Coastal Plain Sands of Rivers State and that of Uzu *et al.,* (1975) for soils of Southeastern Nigeria respectively. The Organic P values obtained was lower when compared with the value of 1.0 - 90 mg kg^{-1}**,** 28.9 - 88 mg/kg, 31.03 - 128 mg kg^{-1} and 62.9 to 132 mg kg^{-1} reported by Lognathan et al. (1982), Osodeke and Kamalu (1992), Ohaeri and Eshett (2011) and Ohaeri (2012) respectively**.** Soils from this location has a very low (< 9%) organic P contribution to the total P. This is at variance with the reports of Uzu *et al.,* (1975), Enwezor *et al.,* (1990), Osodeke and Kamalu (1992) who reported that about 40% of the total P in the surface horizon are in organic P form. This variance could be because of continuous cultivation, old parent rock and overgrazing in the present studied areas. Multiple correlation and regression analysis (Table 5) showed that organic P in Ibeku soils did not correlate with other P forms but correlated positively ($p > 0.05$) with Available P ($r = -0.41^*$). This is contrary to the reports of Azeez *et al.,* (2013). There was no significance correlation with organic carbon contrary to the reports of Udo and Dambo (1979). But the present result agrees with the reports of Osodeke and Kamalu (1992), Ohaeri and Eshett (2011) and Ohaeri (2012). Organic P had a significant negative correlation with sand ($r = -0.56^*$) and positive relationship ($p < 0.05$) ($r = 0.62^*$) with silt (Table 4). The negative correlation of Organic P agrees with the findings of Osodeke and Kamalu (1992).

Occluded P and Inorganic P: Occluded P range of 485.72 mg kg^{-1} in the middle slope to 767.28 mg kg^{-1} in the upper slope with a mean value of 650.13 mg kg^{-1}. Occluded P constituted 75 to 79% of total inorganic P and 66 to 74%of total P across the topo units. The percentage range of occluded P to total inorganic P and total P agrees with that of Osodeke and Kamalu (1992) (30 to 80% and 11 to 67% of occluded P to total inorganic P and total P respectively); Ohaeri and Eshett (2011) and Ohaeri (2012) ***(***40 to 80% and 26 to 68 of occluded P to total inorganic P and total P respectively). Fe-P ranged from 106.45 (for middle slope) to 169.51 mg kg^{-1} (for lower slope) with a mean value of 147.33 mg kg^{-1}. The occluded P and Fe-P occupied more than 90% of the total inorganic P. This result suggests a high degree of chemical weathering of the study soil (Chang and Jackson, 1958). The content of Ca-P and Al-P are very low (< 8% of the total inorganic P). The present study agrees with the report of Ohaeri and Eshett (2011) and Ohaeri (2012). The low Al-P content and the predominance of the occluded P in these soils suggest the limited capacity of the study soil in supplying plant-available P from the inorganic P. The active P constitute between 19 and 22%of the total soil P. These values are comparable to the values (13 to 33%) reported by Osodeke and Kamalu (1992), and 18 to 38%by Ohaeri and Eshett (2011) and Ohaeri (2012). The relative abundance of various forms of inorganic P was in increasing order: Ca-P < Al-P < Fe-P <occluded P. Similar order was reported by authors (Udo and Dambo, 1979 in Nigerian coasted plain sands, Loganathan *et al.,* 1982 in status of some coconut growing soils of sir lanka, Loganathan and Sutton, 1987 in different geological deposit in the Niger Delta area of Nigeria, Osodeke and Kamalu, 1992 in Phosphorus status of Hevea growing soils of Nigeria, Ojo *et al.,* 2010, Ohaeri and Eshett, 2011 in selected soils formed over different parent materials in Abia of Nigeria and Ohaeri, 2012 in selected soils formed over different parent materials in Cross River state of Nigeria.). The high content of Al-P in the lower horizons of the soil is due to poor drainage condition rather than degree of weathering. Similar reports were made from Uzu (1975), Ohaeri and Eshett (2011). Occluded P correlated negatively with Mg alone ($r = -0.40^*$, Table 4). Fe-P correlated positively with Occluded P, Ca-P, Al-P and total P. Occluded P correlated positively with Al-P, Fe-P, Ca-P, and total P (Table 5).

Available phosphorus: Available P ranged from 19.7 mg kg^{-1} for middle slope to 29.96 for valley bottom with mean value of 23.42 mg kg^{-1}. Overall, the available P soil of study area was above the critical levels of 15 mg kg^{-1} (Enwezor *et al.,* 1989; Enwezor *et al.,* 1990). Available P did not correlate with the other soil properties but correlated negatively ($p < 0.05$) with Ca-P ($r = -0.41^*$) and Organic-P ($r = -0.41^*$).

Conclusion

The studied soil varied widely in their P status across the toposequence. Total P distribution was irregular and it varied with soil depth across the toposequence. Soils of Amaeke Ibeku has low (< 9%) organic P contribution to the total P. Occluded P constituted 66 to 74% and 75 to 79% of total P and total inorganic P forms, respectively. Occluded P and Fe-P occupied were more than 90% of the total inorganic P, while active inorganic P constituted 19 and 22% total P. Ca-P and Al-P were very low (< 8%) in soils. Lower horizons of the study soil had low Al-P content and high Fe-P content. The relative abundance of various forms of inorganic P were in the sequence of Ca-P < Al-P < Fe-P < occluded P. In general, the soil available P was above the critical level 15 mg/kg).

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Table 1. Selected physical properties the soils

Units	Dept (cm)	Sand (%)	Silt (%)	Clay (%)	Texture	Silt/clay Ratio
Crest	0-20	68.00	16.00	16.00	Sandy loam	1.00
	20-40	58.00	10.00	32.00	Sandy clay loam	0.31
	40-60	56.00	12.00	32.00	Sandy clay loam	0.37
	60-80	52.00	8.00	40.00	Sandy clay	0.20
	80-100	27.00	13.00	60.00	Clay	0.22
Upper slope	0-20	52.00	8.00	40.00	Sandy clay	0.20
	20-40	50.00	10.00	40.00	Sandy clay	0.25
	40-60	48.00	12.00	40.00	Sandy clay	0.30
	60-80	44.00	8.00	48.00	Sandy clay	0.16
	80-100	31.00	9.00	60.00	Sandy clay loam	0.15
Middle slope	0-20	36.00	16.00	48.00	Sandy clay loam	0.33
	20-40	18.00	22.00	60.00	Clay	0.36
	40-60	42.00	14.00	48.00	Sandy clay	0.29
	60-80	64.00	20.00	16.00	Sandy loam	1.25
	80-100	37.00	11.00	52.00	Sandy clay	0.21
Lower slope	0-20	51.00	13.00	36.00	Sandy clay loam	0.36
	20-40	26.00	10.00	64.00	Clay	0.15
	40-60	10.00	14.00	76.00	Clay	0.18
	60-80	22.00	14.00	64.00	Clay	0.22
	80-100	12.00	12.00	76.00	Clay	0.16
Valley bottom	0-20	62.00	14.00	26.00	Sandy clay loam	0.54
	20-40	41.00	15.00	44.00	Sandy clay	0.34
	40-60	43.00	13.00	44.00	Sandy clay	0.29
	60-80	43.00	13.00	44.00	Sandy clay	0.29
	80-100	27.00	13.00	60.00	Clay	0.22

Table 2. Selected chemical properties the soils

Units	Dept (cm)	pH (H_2O)	OC (%)	Av-P (mg kg^{-1})	TEA	Ca	Mg	Na	ECEC	BS
					← (Cmol kg^{-1})					→ (%)
Crest	0-20	4.4	0.71	14.8	21.6	6.0	3.6	0.62	32.0	32.5
	20-40	5.0	0.32	25.8	25.6	5.2	2.9	0.35	34.3	25.4
	40-60	5.2	0.78	14.2	17.2	6.0	2.0	0.29	25.7	33.0
	60-80	4.6	0.42	14.2	21.4	3.0	2.4	0.26	27.2	21.4
	80-100	4.4	0.28	15.3	17.4	4.8	3.6	0.22	26.2	33.6
Upper slope	0-20	4.5	2.30	14.2	17.2	4.0	3.2	0.33	24.9	30.8
	20-40	5.2	0.82	22.5	10.4	4.4	3.2	0.40	18.5	43.8
	40-60	5.4	0.35	15.9	9.20	4.4	2.4	0.82	16.9	45.6
	60-80	4.3	0.80	32.9	17.2	3.6	2.2	0.31	23.4	26.5
	80-100	4.2	0.57	24.1	8.00	4.8	3.2	0.39	16.5	51.6
Middle slope	0-20	4.5	1.21	16.4	2.00	4.4	4.0	0.65	11.2	82.1
	20-40	4.8	0.53	14.2	2.20	4.8	4.0	0.27	11.4	80.8
	40-60	4.8	0.17	24.7	2.00	4.0	2.8	0.20	9.12	78.1
	60-80	4.3	0.17	10.9	3.20	4.0	3.2	0.26	10.8	70.3
	80-100	4.8	0.21	14.8	2.00	3.6	2.8	0.25	8.78	77.2
Lower slope	0-20	4.6	1.10	11.5	5.32	4.4	2.4	0.38	12.6	58.6
	20-40	4.5	2.30	14.2	2.4	3.6	2.0	0.28	8.45	71.6
	40-60	5.8	1.28	16.4	4.8	5.2	2.0	0.49	12.6	62.0
	60-80	4.8	0.96	10.4	4.4	3.6	2.4	0.27	10.8	59.2
	80-100	5.0	0.49	17.0	5.6	4.8	2.4	0.33	13.3	578
Valley bottom	0-20	4.8	2.14	14.8	1.6	5.2	2.4	0.16	9.50	83.2
	20-40	4.3	0.49	16.4	2.4	4.0	3.6	0.33	10.7	77.6
	40-60	4.7	1.35	14.2	1.2	4.8	2.0	0.31	8.44	85.8
	60-80	4.4	0.60	13.1	2.0	3.2	2.4	0.51	8.23	75.7
	80-100	5.0	0.57	12.0	1.2	6.0	2.8	0.85	11.8	89.1

Av-P = Available P, OC = Organic carbon, TEA = Total Exchangeable Acidity,
ECEC = Effective Cation Exchange Capacity and BS = Base Saturation

Table 3: Forms of phosphorus in Amaeke Ibeku soils (mg kg-1)

Units	Dept (cm)	Org-P	Tot-P	Occl-P	Fe-P	Ca-P	AL-P	Av-P
Crest	0-20	131	1475	1041	214	37.4	51.9	23.0
	20-40	108	1382	938	238	44.7	52.7	10.4
	40-60	115	1317	927	216	48.7	10.8	13.1
	60-80	155	340	143	26.9	1.94	12.8	40.0
	80-100	158	440	145	69.7	10.8	56.8	15.9
Upper Slope	0-20	66.9	1370	106	158	42.3	43.1	29.0
	20-40	46.8	489	356	76.9	0.29	8.38	15.3
	40-60	55.6	473	315	101	0.26	0.31	18.1
	60-80	23.4	1513	1099	261	55.2	68.9	29.0
	80-100	12.1	1362	1006	216	52.7	74.5	37.8
Middle Slope	0-20	177	499	266	21.3	9.19	24.5	19.7
	20-40	273	1477	872	238	44.7	48.7	19.2
	40-60	112	499	287	69.7	10.0	19.7	18.1
	60-80	194	1136	701	141	42.3	56.8	18.1
	80-100	71.0	469	302	61.6	9.19	24.5	23.6
Lower Slope	0-20	119	577	335	79.4	19.7	24.5	13.7
	20-40	192	1632	1053	291	45.5	50.3	12.6
	40-60	222	1317	753	254	43.1	44.7	15.9
	60-80	122	215	51	41.5	0.21	0.24	24.1
	80-100	107	1448	1060	182	51.9	47.1	38.9
Valley Bottom	0-20	72.6	487	369	35.0	1.94	8.38	38.4
	20-40	85.5	535	347	72.1	18.1	12.4	32.3
	40-60	135	1144	730	181	43.1	55.2	16.1
	60-80	57.3	1422	1043	254	31.0	36.6	38.9
	80-100	54.8	139	1053	178	51.9	52.7	24.1

Org-P = Organic Phosphorus, Tot-P = Total Phosphorus, Occl-P = Occluded Phosphorus, Fe-P = Iron Phosphorus, Ca-P = Calcium Phosphorus, Al-P = Aluminum Phosphorus, Av-P = Available Phosphorus,

Table 4: Correlation between soil properties and soil phosphorus forms

	Al-P	Fe-P	Ca-P	Organic P	Occluded P	Available P	Total P
Sand	0.09	-0.11	-0.13	-0.56*	0.02	0.09	-0.08
Silt	-0.21	-0.06	-0.01	0.62*	-0.11	-0.21	-0.01
Clay	0.06	0.19	0.17	0.16	-0.05	0.06	0.11
Silt/Clay ratio	0.07	-0.03	0.04	0.25	0.04	-0.12	0.07
Ph	-0.25	-0.14	-0.26	-0.02	-0.19	-0.25	-0.20
TEA	-0.06	-0.14	0.10	-0.13	0.15	-0.06	0.13
O/c	-0.09	-0.09	-0.06	-0.01	-0.05	-0.09	-0.06
Ca^{+}	0.17	-0.13	-0.01	0.01	-0.04	0.17	-0.06
Mg^{+}	-0.11	-0.34	-0.27	0.13	-0.40*	-0.11	-0.38
K^{+}	-0.18	-0.19	-0.33	0.11	-0.28	-0.18	-0.26
Na^{+}	0.28	-0.24	-0.15	0.19	-0.20	0.28	-0.19
ECEC	-0.01	0.04	0.07	-0.13	-0.07	-0.01	0.05
B.S	0.06	-0.13	0.07	0.20	-0.12	0.06	-0.10

* Significant at p < 0.05. Org-P = Organic Phosphorus, Tot-P = Total Phosphorus, Occl-P = Occluded Phosphorus, Fe-P = Iron Phosphorus, Ca-P = Calcium Phosphorus, Al-P = Aluminum Phosphorus, Av-P = Available Phosphorus

Table 5: Correlation among various forms of phosphorus

	Al-P	Fe-P	Ca-P	Organic P	Occluded P	Available P
Fe-P	0.67**	-				
Ca-P	0.78**	0.86**	-			
Organic P	0.09	0.09	0.06	-		
Occluded P	0.69**	0.90**	0.91**	-0.09	-	
Available P	-0.01	-0.12	-0.41*	-0.41*	0.08	-
Total P	0.73**	0.94**	0.08	0.08	0.98**	-0.01

* Significant at p < 0.05, ** Significant at p < 0.01.

ASN 53rd Annual Conference Proceedings (Sub-Theme: Soil Conservation, Fertility and Water Mgt.)

Forms and Profile Distribution of Potassium Along a Toposequence in Amaeke Ibeku Soil, Umuahia Abia State

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Abstract
A study was carried out to assess the forms and distribution of potassium (K) along a toposequence of Amaeke Ibeku Umuahia North LGA of Abia State of Nigeria were investigated in 2017. Five pedons representing crest, upper slope, middle slope, lower slope and valley bottom were assessed. A total of 25 auger soil samples were collected from 0-20, 20-40, 40-60, 60-80, 80-100 cm depth from the five sampling units along a toposequence. The samples were analyzed for various forms of K and other physical and chemical properties. Soil K varied widely and the distribution of various forms of K within soil depth and along a toposequence was not uniform. There was no direct relationship between total K and other forms of K in Amaeke Ibeku soils except Residual K. Soil solution K was lowest in comparison with other K forms across the toposequence. K-Reserve and Residual-K constitute on average 21.70% and 78% total K in soils, respectively. The soil K forms in the order of their availability were in the sequence of exchangeable-K > difficultly exchangeable-K > K supplying > K reserve > K residual > total K. Influence of various soil K forms on available K was positive with exchangeable K having the highest coefficient of determination. The soils were rated low in exchangeable K. Total K and its various there are influenced by topography. The studied soils have potentials for sustainable arable production but requires high K fertilizer application

Keyword: Toposequence, Potassium, Exchangeable-K, Total-K, K-distribution

Introduction

Potassium (K) is an essential plant nutrient next to Nitrogen (N). Crops absorb K in greater amounts than any other nutrient. Potassium exists in four major forms in the soil. These include solution, exchangeable, non-exchangeable or fixed and mineral or structural K forms (Sparks, 1987; Sparks, 2000). Equilibrium and kinetic reactions exist between K forms in the soils and this affects their solution concentration and availability to plants (Ano, 1991; Ndukwu *et al*., 2012). As soil solution K concentration is depleted through leaching and plant uptake, it is immediately replenished by the other forms especially the exchangeable and non-exchangeable fractions (Yawson *et al*., 2011). Thus, K availability K in soil solution is influenced by the solution-exchangeable K dynamics, rate of K exchange in soil, K fixation and release from soil minerals and leaching (Sparks, 2000). Variations in soil K status is associated with factors imposed by certain soil physicochemical properties (Ndukwu *et al*., 2012). Topography is an important factor that affects the nature and distribution of soils along a toposequence, and soil pattern can be differentiated on the bases of various characteristics (Esu *et al.,* 2008). Topography can affect soil chemical and physical properties due to differences in slope position and consequently affect crop yield. Ayodele *et al.* (1983) reported that variations in soil properties along a toposequence were spatially dependent. Ogban *et al.* (1999) deduced that nutrient status and soil properties are related to topography. Studies on K status for most soils in the tropic, Nigeria in particular, are concerned with their relationships with the parent materials (Adepetu *et al*., 1988; Ndukwu *et al*., 2012). There is dearth of information on the relationship between soil K status and the toposequence. Study on the effect slope position on K status of soils of Amaeke Ibeku will provide vital information needed for K fertilizer management to achieve sustainable crop production in Amaeke Ibeku. The objectives of the

study are to: (i) determine some chemical and physical properties of soils along the toposequence (ii) determine the effect of toposequence on the forms of K and their distribution along a toposequence.

Materials and Methods

This study was conducted along toposequence of Amaeke Ibeku soils in Umuahia North Local Government Area of Abia State. The study area is located on latitude 5^{o} 32′ N and longitude 7^{0} 33′ E. The site was geo-referenced using handheld Global Positioning System (GPS) Receiver (Garmin Ltd Kansas, USA). The toposequence was delineated into five units viz: Crest, Upper slope, Middle slope, Lower slope and Valley bottom. Soil samples were collected at 0-20, 20-40, 40-60, 60-80, 80-100 cm depth, respectively using a soil auger. Soil samples were air-dried at room temperature for 3 days. The air-dried soil samples were gently crushed with a wooden roller and sieved through a 2 mm sieve for some chemical analysis. Also, a small portion of the air-dried sample were crushed with a mortar and sieve through 0.5 mm sieve for organic carbon determination. Particle size distribution was determined by hydrometer method using sodium heaxmetaphosphate (calgon) as dispersing agent (Gee and Or, 2002). soil pH was determined in water using Bechman's pH meter in a soil to water ratio of 1:2.5 (Thomas, 1996). Organic carbon was determined by the dichromate wet oxidation method(Nelson and Sommers, 1996). Soil total K was determined by perchloric acid digestion method (Pratt, 1965) and nitric acid (HNO3) extractable K or K-supplying power was determined as described by Haylock (1965). 10 M HCl extractable K (Finck, 1962) was determined by boiling a 1:10 soil acid suspension. K-reserve was obtained by the difference between 10 M HCl extracted K and exchangeable K plus soluble K (Piper, 1950). Residual K was calculated as the difference between total K and K-reserve. Solution K was extracted using distilled water while the exchangeable K was determined using 1 N NH4OAc solution and K in the extracts using

flame photometer (Thomas, 1996). Available K was obtained as a summation of solution K and exchangeable K. Exchangeable bases (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}) were extracted with 1 N ammonium acetate (NH_4OAc) at pH 7.0. Calcium and Mg in the extracts were determined by titration (Jackson, 1958) while Na^{+} and K^{+} were determined with flame photometer. Exchangeable hydrogen and Al^{3+}(TEA) were determined by the method outlined by Mclean (1982). Effective cation exchange capacity (ECEC) was calculated as the sum of total exchangeable bases and total exchangeable acidity (Tan, 1996). Percentage base saturation was calculated as outlined by Coleman and Thomas (1967). Available P was determined by Bray II method (Bray and Kurtz, 1945). Phosphorus concentration in soil extracting solution was determined colorimetrically using ascorbic acid method (Kuo, 1996) on a spectrophotometer set to 880 nm.

Data analysis: Data on soil K forms and some selected soil chemical properties were collected and analyzed using package of GenStat Release computer (2018). Pearson correlation analyses were also performed to determine the intent of the relationship among the various K forms, between the K with other soil properties. The significance of the relationship was tested at $p < 0.05$.

Results and Discussion

The results of soil physical and chemical properties are in Tables 1 and 2. silt/clay ratios ranged from 0.15-1.25 and their means is less than unity (0.53), indicating that the soils are old and highly weathered (Essoka and Esu, 2005).

Total potassium: Total K content of the study area ranged from 1.68 to 18.45 cmol/kg with a mean value of 10.11 cmol/kg (Table 3). Total K distribution within soil depth across the toposequence was not only irregular but varied widely. Total K was highat the crest, but decreased at the upper slope and middle slope then increased at the lower slope and valley bottom. A similar sequence of Total K distribution along a toposequence has been reported for soils of Amaoba-Ime, Ikwuano Local Government Area of Abia State. In that studies, the total K ranged from 1.68 to 6.57cmol/kg (Inyama, 2004). This total K value is low relative to values of 5.58- 10.15 cmol/kg, 7.17- 11.10 cmol/kg, 2.69-23.21 cmol/kg and 11.65- 20.35 cmol/kg reported by Ano *et al* (1991), Ndukwu (2005) and Uzoho and Ekeh (2014) for Coastal Plain Sands of Southeastern Nigeria, respectively. Similarly, relatively higher total K values of 12-17 cmol/kg have been reported by Ngwe *et al.,* (2012) for tropical savannah Thailand soils. The low total K content of Amaeke Ibeku soils is ascribed to the low K content of the parent materials from which the soils were formed and also due to high weatherability of the parent materials (Akamigbo and Asadu, 1983; Enwezor *et al.*, 1990; Samuel *et al*., 2003). The highest average total K (6.57 cmol/kg) was at the crest, while the lowest average total K was at the middle slope (1.68 cmol/kg). Total K correlated significantly ($p < 0.05$) with pH (r = 0.54*), Ca^{2+} (r = 0.45*), Na^{+} (r = 0.48*) and % BS (r = 0.53*), negative significance with TEA (r = -0.43*) (Tables 4). This result agrees with the findings of Uzoho and Ekeh (2014) for their study in Ngor-Okpala Coastal Plain Sands of Eastern Nigeria. Contrary to the report of Inyama (2004), but in agreement with Uzoho and Ekeh (2014), total K did not correlate significantly with soil OC (r = -0.20). There was no correlation between total K with sand (r = 0.19), silt (r =-0.18), clay (r = -0.12) and silt/clay ratio (r = 0.09) in the studied soil. This was similar to Inyama (2004) for

Amaoba-Ime soil and Ano *et al.,* (1991) for Amakama soil. However, this finding is not in agreement with that of Uzoho and Ekeh (2014) that had earlier reported a significant correlation coefficient between total K with silt (r = 0.42*) and silt/clay ratio (r = 0.52*) and a negative significant correlation with clay (r = -0.59*) in Ngor-Okpala soils of Imo State in Southeastern Nigeria. The results of the correlation coefficient (r) between the paired soil K forms showed that the contributions of the K forms to total K were low except residual K (Table 4). There was no direct relationship between total K and other forms of K in the studied soils except residual K that correlated positively and highly significant ($p < 0.01$) with soil total K (r = 0.93**). The result obtained is consistent with the findings of Uzoho and Ekeh (2014), butcontrary to Iyama (2004). the

Water soluble potassium : Water soluble K concentrations ranged from 0.02 cmol/kg (middle slope) at 40 – 60 depths and 0.055 cmol/kg (upper slope) at 20 – 40 depths with an average of 0.033 cmol/kg which constitute 0.77% of the total K in soils (Table 3). Studies have reported values of 0.005-0.072 cmol/kg and 0.015-0.031 cmol/kg for Amaoba-Ime soils (Inyama, 2004 and Ndukwu, 2005) respectively, 0.002-0.022 cmol/kg for Ngor-Okpala soils (Uzoho and Ekeh, 2014), 1-11.2 cmol/kg (0.003-0.028 cmol/kg) for major Lebanese agricultural soils (Al-Zubaidi *et al.*, 2008) and 1.56 -17.94 cmol/kg (0.004-0.046 cmol/kg) for paddy and non-paddy soils in Iran (Raheb and Heidari, 2011). These values are relatively low when compared with that recorded for the present study. Thus, suggesting that solution K constitute an insignificant fraction of K available for plant uptake. In the soil, the lowest value of solution K is 0.01 at the lower slope at the depth of 20 – 40 cm while the highest value is 0.06 cmolkg at crest at depth of 40 – 60 and valley bottom at depth of 40 – 60 cm. Solution K concentration in the soils studied, across the toposequence, were lowest in comparison with other soil K forms (0.033cmolkg). The highest mean values of solution K was obtained from the crest, while the least value came from the middle slope. Similar finding has been reported by Inyama (2004). It has been shown that the level of water soluble K is generally low except soils that have been recently amended with K fertilizers (Spark, 2000; Taylor and Francis, 2000). There was no significant relationship between solution K and all the selected soil properties. Correlation between solution K with K reserve was significant in the soil (0.44*). Solution K^+ correlated significantly ($P < 0.01$) with available K^+ (r = 0.91**).

Difficulty exchangeable potassium in the soils: The difference between 1M HNO_3 acid extractable K (K-supplying powers) and exchangeable K otherwise referred to as difficulty exchangeable or slowly available K (Graley *et al.*, 1960) ranged from 0.04 - 0.42 cmol/kg with mean values of 0.23 cmol/kg in the soils. This range reported is comparable with range of 1.02 -1.53 cmol/kg (Inyama, 2004) and 0.02-0.68 cmol/kg (Ndukwu, 2005) of two soils of contrasting parent materials in Abia State, Nigeria. Difficulty exchangeable K constitute on average 6.6% of total K in soils. The least mean values of difficulty exchangeable K was obtained from the middle slope (0.04 cmol/kg) soils, while the highest mean values came from the valley bottom (0.35cmol/kg). When related to the physico-chemical properties of soils, difficulty exchangeable K positively and significantly ($P < 0.05$) correlated with only soil available P (r = 0.45*). Moreover, difficulty exchangeable K correlated positively and highly significantly ($P < 0.01$) with K supplying power (r = 0.99**) only (Table 5).

Potassium supplying power of the soils: HNO_3 acid extractable K is also known as K- supplying powers (Haylock, 1956). This form of K ranged from 0.18 to 0.54 cmol/kg with a mean value of 0.46 cmol/kg. This range is comparable with 0.4-0.89 cmol/kg and 0.09-0.23 cmol/kg obtained by Ndukwu (2005) and Ndukwu *et al*. (2012) in soils Underlain by Three Lithologies South Eastern Nigeria, for soils of contrasting parent material (Amaoba-Ime and Amaeke-Ibeku) and soils of varying lithologies (shale, upper coal measure and lower coal measure) respectively. Moreover, this range is low relative to the ranges of 1.07-1.74 cmol/kg in Amaoba soil (Iyama, 2004). K-supplying power constitute on average 10.70% of total K in soils. Soils with K supplying power which ranged between 0.31 and 0.49 cmol/kg, as measured by 1M $HN0_3$, have been classified as having potential for response to K fertilization especially if K removal is intensive and the soils are coarse textured (Ano *et al*., 1991; Ano, 1994). Therefore, with exception of middle slope (0.18cmol/kg) that is deficient in K and requires intense supply of K fertilizer, the other Topo units have the potential for response to minimal amount K fertilization. The trend observed in the mean values of difficulty exchangeable K was maintained in the mean values of K supplying power with the least mean values obtained from the middle slope (0.18 cmol/kg), while the highest mean values also came from the valley bottom. Multiple correlation and regression analysis (Tables 4) showed that results of difficulty exchangeable K with soil physico-chemical properties were similar to that of K supplying power and physico-chemical properties in the soils. Consequently, K supplying power was found to be positively and significantly ($P < 0.05$) correlated with only soil available P (r = 0.44*).

Potassium reserve/HCl extractable potassium: Potassium reserve determined by 10 M HCl extraction was higher in all the samples than 1M HNO_3 extractable K and this was in agreement with the findings of Iyama (2004), Ndukwu (2005) and Ano *et al*., (1991) in potassium status of the Nigerian Coastal Plain sand. The highest value is 4.96 cmol/kg at crest at a depth of 40 – 60 cm while the lowest value is 0.12 cmolkg at the middle slope at a depth

of 20 – 40 cm, with a mean value ranging from 0.32 -1.75 cmol/kg. K-reserve range in these soils is comparable with that obtained by Ndukwu (2005) but low relative to that reported by Iyama (2004). Soils K- reserve constitute on average 21.70%. Potassium reserve correlated positively and significantly ($P < 0.05$) with soil Ca^{2+} ($r = 0.43^*$), organic carbon ($r = 0.62^{**}$) and Na^+ ($r = 0.46^*$). Strong ($P < 0.01$) relationship has been reported between K-reserve and soil Organic carbon (Iyama, 2004). Soils K-reserve correlated positively and highly significantly ($P < 0.01$) with soil available K ($r = 0.52^*$) and solution K ($r = 0.44^*$) only.

Residual potassium: Residual-K ranged from 1.36 to 4.83 cmol/kg. The residual-K range obtained is comparable with 2.52-22.27 cmol/kg reported by Ndukwu (2005) which constituted an average of 78.45% of total K. The low mean values of residual- K was obtained from the middle slope (1.36cmol/kg), while the highest values came from the crest (4.83cmol/kg). Residual-K correlated positively and significantly ($P < 0.05$) with soil pH, Na^+ and BS ($r = 0.53^*$,

Available potassium in the soil: The availability of soil K forms are in the sequence: exchangeable K > difficultly exchangeable K > K- supplying power > K-reserve > residual-K > total K. This order has been reported by some researchers (Spark, 2000; Ndukwu, 2005). Available K is the summation of solution K and exchangeable K (Tables 3). These values (0.15-0.25 cmol/kg) are low relative to ranges of 49.7-803.14 cmol/kg for low land vertisols in tropical savannah climate of Thailand soils (Ngwe *et al.,*2012), 132.74 - 546.59 cmol/kg for Lake basin Ethiopian soils (Ayele, 2013) and 0.40 - 0.92 cmol/kg ultisols in Ngor-Okpala soils (Uzoho and Ekeh, 2014). The trend observed in the mean values of exchangeable K was maintained in the mean values of available K with the highest mean values of available K obtained from the crest (0.25 cmol/kg), while the least values came from the upper slope (0.15 – 0.28) in soils. Available K constitute on average 4.51% of total K in soils. The relationships among various K forms (Tables 5) showed that available K significantly ($P < 0.01$) correlated with solution K ($r = 0.91^{**}$) and K- reserve ($P < 0.05$) ($r = 0.52^*$) not significantly ($P > 0.05$) correlated with all other forms of K. Studies have reported significant ($P < 0.05$) correlation between soil available K and exchangeable K (Ayele, 2013) and between HNO_3 extractable K with non-exchangeable, exchangeable and total K (Ngwe *et al*., 2012). The relationship among soil K forms (Tables 6) revealed that the influence of the soil K forms on available K was positive. The highest coefficient of determination was recorded in equation relating available K to exchangeable K. Regression models explained the relationship between available K and other soil K forms. A regression equation of the form $Y = -0.031 + 0.993 X$ indicated that exchangeable K accounted for about 94% of the soil available K. This result is anticipated since exchangeable K is the major source of K available to plant (Pal *et al.,* 2001). Also a regression equation $Y = 0.029 + 1.39 X$ explained that 9% of the soil available K was due to difficulty K. Further, a regression model $Y = -0.001+ 2.383X$ showed that the K-supplying power was responsible for 10% of available K while $Y = 0.177 + 3.864 X$ showed that 5% of available K was contributed by K-reserve. The regression equation $Y = 2.483 + 4.442 X$ explained that 1% of available K was due to residual K while $Y = 2.66+ 8.307X$ showed that 4% of available K was contributed by total K. The slope of the regression models confirmed the importance total K (+ 8.307), residual- K (+ 4.442), K- reserve (+ 3.864), K- supplying power (+ 2.383), difficulty K (+ 1.390) and exchangeable K (+ 0.993) to the soils available K status.

Conclusion

All K forms in soils of the study area varied widely with depth and across the toposequence. Similarly, distribution of K forms within soils depth and across the toposequence was not uniform. There was no direct relationship between total K and other forms of K in the soils except residual K. Solution K concentration, across the toposequence, were lowest compared with other soil K forms. Results of difficulty exchangeable K with soil physico-chemical properties were similar to that of K supplying power and physico-chemical properties of the soils. K-reserve constitute on average 21.70% and 10.20% of total K, while residual K constituted about 90% and 78% of total K. The forms of K in soil in the order of their availability were in the sequence: exchangeable K > difficultly exchangeable K > K- supplying power > K-reserve > residual K > total K. Influence of the soil K forms on available K was positive with exchangeable K having the highest coefficient of determination. The results indicate that the status of K and its forms are influenced by topography. This study suggests the use high rates of application K fertilizer to improve the K fertility status of the soil.

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Table 1. Selected physical properties the soils

Units	Dept (cm)	Sand (%)	Silt (%)	Clay (%)	Texture	Silt/clay Ratio
Crest	0-20	68.00	16.00	16.00	Sandy loam	1.00
	20-40	58.00	10.00	32.00	Sandy clay loam	0.31
	40-60	56.00	12.00	32.00	Sandy clay loam	0.37
	60-80	52.00	8.00	40.00	Sandy clay	0.20
	80-100	27.00	13.00	60.00	Clay	0.22
Upper slope	0-20	52.00	8.00	40.00	Sandy clay	0.20
	20-40	50.00	10.00	40.00	Sandy clay	0.25
	40-60	48.00	12.00	40.00	Sandy clay	0.30
	60-80	44.00	8.00	48.00	Sandy clay	0.16
	80-100	31.00	9.00	60.00	Sandy clay loam	0.15
Middle slope	0-20	36.00	16.00	48.00	Sandy clay loam	0.33
	20-40	18.00	22.00	60.00	Clay	0.36
	40-60	42.00	14.00	48.00	Sandy clay	0.29
	60-80	64.00	20.00	16.00	Sandy loam	1.25
	80-100	37.00	11.00	52.00	Sandy clay	0.21
Lower slope	0-20	51.00	13.00	36.00	Sandy clay loam	0.36
	20-40	26.00	10.00	64.00	Clay	0.15
	40-60	10.00	14.00	76.00	Clay	0.18
	60-80	22.00	14.00	64.00	Clay	0.22
	80-100	12.00	12.00	76.00	Clay	0.16
Valley bottom	0-20	62.00	14.00	26.00	Sandy clay loam	0.54
	20-40	41.00	15.00	44.00	Sandy clay	0.34
	40-60	43.00	13.00	44.00	Sandy clay	0.29
	60-80	43.00	13.00	44.00	Sandy clay	0.29
	80-100	27.00	13.00	60.00	Clay	0.22

Table 2. Selected chemical properties the soils

Units	Dept (cm)	pH (H_2O)	OC (%)	Av.Pmg/kg	TEA	Ca	Mg	Na	ECEC	BS (%)	
					← Cmol/kg					→	
Crest	0-20	4.50	1.71	23.00	1.20	8.00	0.80	0.44	10.73	88.82	
	20-40	5.20	0.92	10.40	1.60	10.00	2.00	0.35	14.27	88.79	
	40-60	4.30	0.49	13.10	0.80	4.80	2.80	0.41	9.08	91.19	
	60-80	4.40	0.35	40.00	1.20	8.80	1.60	0.46	12.26	90.21	
	80-100	4.20	0.71	15.90	2.00	4.80	2.00	0.36	9.36	78.63	
Upper slope	0-20	4.70	0.17	29.00	2.40	5.60	0.80	0.39	9.40	74.47	
	20-40	4.40	0.57	15.30	3.60	4.80	2.40	0.35	11.36	68.31	
	40-60	5.50	0.42	18.10	1.20	4.40	3.20	0.39	9.49	87.36	
	60-80	4.60	0.71	29.00	2.40	7.60	1.60	0.38	12.20	80.33	
	80-100	4.50	0.21	37.80	2.40	6.00	2.80	0.40	11.79	79.64	
Middle slope	0-20	5.00	0.71	19.70	2.40	8.80	6.00	0.47	17.93	86.61	
	20-40	4.70	0.14	19.20	1.20	7.60	2.00	0.36	11.47	89.54	
	40-60	5.50	1.17	18.10	2.40	10.80	1.20	0.35	15.15	84.16	
	60-80	4.50	0.67	18.10	2.80	9.60	2.80	0.44	15.84	82.32	
	80-100	4.80	0.28	23.60	2.40	11.60	2.00	0.37	16.65	85.59	
Lower slope	0-20	4.60	1.14	13.70	2.80	13.60	2.40	0.39	19.50	85.64	
	20-40	4.60	0.71	12.60	1.60	11.60	2.40	0.41	16.24	90.15	
	40-60	4.60	1.14	15.90	0.80	8.80	2.40	0.49	12.78	93.74	
	60-80	4.30	0.14	24.10	1.20	8.80	5.60	0.55	16.43	92.70	
	80-100	4.40	0.14	38.90	1.20	10.40	2.40	0.44	14.65	91.81	
Valley bottom	0-20	4.60	2.21	38.40	1.60	13.60	2.40	0.45	18.45	91.33	
	20-40	4.60	1.35	32.30	1.60	16.00	4.00	0.45	22.32	92.83	
	40-60	4.20	1.35	16.40	1.60	10.80	4.40	0.32	17.37	90.79	
	60-80	4.30	0.35	38.90	1.60	10.00	2.00	0.37	14.22	88.75	8.23
	80-100	4.20	1.34	24.10	2.00	14.80	2.00	0.44	19.45	89.72	11.80

OC = Organic carbon, TEA = Total Exchangeable Acidity, ECEC = Effective Cation Exchange Capacity and BS = Base Saturation

Table 3. Forms of potassium in soils of Amaeke-Ibeku(cmolkg-^{1})

Units	Dept(cm)	Avail-K	Wsol-K	Exch-K	Diff-K	K-Sup	K-Resv	Resi-K	Tot-K
Crest	0-20	0.37	0.09	0.28	1.73	2.20	5.23	6.15	11.38
	20-40	0.36	0.05	0.32	1.03	1.34	0.76	18.45	19.2
	40-60	0.33	0.06	0.27	1.34	1.61	1.86	16.71	18.57
	60-80	0.25	0.05	0.19	1.25	1.44	2.20	7.61	9.80
	80-100	0.26	0.06	0.2	0.74	0.95	1.09	11.12	12.21
Upper Slope	0-20	0.27	0.05	0.21	0.74	0.94	0.83	15.87	16.69
	20-40	0.28	0.07	0.21	1.6	1.82	1.08	9.14	10.22
	40-60	0.37	0.08	0.29	0.69	0.98	0.75	13.75	14.50
	60-80	0.27	0.05	0.21	0.75	0.96	1.28	12.39	13.69
	80-100	0.22	0.02	0.19	0.66	0.87	0.89	13.69	14.5
Middle Slope	0-20	0.39	0.14	0.26	1.51	1.76	1.71	13.32	15.03
	20-40	0.40	0.09	0.31	1.66	1.96	1.46	23.44	24.89
	40-60	0.46	0.06	0.4	1.67	2.08	0.64	11.08	11.72
	60-80	0.25	0.05	0.2	1.98	1.19	0.95	11.05	12.00

	80-100	0.33	0.05	0.28	1.22	1.5	0.86	27.73	28.59
Lower Slope	0-20	0.40	0.09	0.31	1.45	1.76	1.98	6.27	8.24
	20-40	0.34	0.11	0.23	0.27	0.5	1.59	20.01	21.6
	40-60	0.37	0.08	0.29	1.99	2.28	2.36	11.62	13.97
	60-80	0.37	0.09	0.27	1.28	1.56	2.05	16.11	18.16
	80-100	0.32	0.11	0.21	1.23	1.45	1.29	13.01	14.29
Valley Bottom	0-20	0.48	0.09	0.39	2.66	3.06	4.34	15.91	20.23
	20-40	0.35	0.08	0.27	1.61	1.88	2.18	17.63	19.81
	40-60	0.34	0.09	0.25	1.25	1.50	1.15	18.99	20.14
	60-80	0.33	0.08	0.25	1.05	1.29	1.25	12.42	13.67
	80-100	0.25	0.04	0.21	1.19	1.39	1.14	14.62	15.75

Avail-K = Available K^+, Wsol-K =Water Soluble K^+, Exch-K = Exchangeable K^+, Diff-K = Difficulty K^+, K-Sup = K^+ Supply, K–Res = K^+ Reserve, K-Resi = ResidualK^+, Tot-K = Total K^+.

Table 4. Correlation coefficient between soil properties and soil potassium forms

	Avail	Wsol	Exch	Diff-	K-Su	K-res	K-re	Tot-K
Sand	-0.18	-0.38	-0.03	-0.14	-0.14	0.10	-0.25	-0.24
Silt	0.41*	0.38	0.31	0.43*	0.44*	0.25	0.07	0.13
Clay	-0.12	0.15	-0.21	-0.18	-0.19	-0.34	0.25	0.18
pH	0.49*	0.04	0.57*	0.01	0.07	-0.18	0.10	0.06
Exch- A	-0.32	-0.37	-0.21	-0.24	-0.24	0.10	-0.31	-0.30
O/c	0.46*	0.12	0.50	0.58*	0.59*	0.62*	-0.21	-0.08
OM	0.66*	0.21	0.69*	0.68*	0.70*	0.59*	-0.10	0.02
Avail-P	-0.19	-0.11	-0.17	0.10	0.07	0.19	-0.10	-0.06
Ca^+	0.32	0.16	0.30	0.33	0.33	0.22	0.17	0.23
Mg^+	0.17	0.50*	-0.03	0.06	0.05	-0.05	0.18	0.17
Na^+	0.06	0.27	-0.05	0.27	0.24	0.46*	-0.19	-0.09
TEB	0.36	0.33	0.27	0.32	0.33	0.18	0.22	0.27
ECEC	-0.19	-0.33	0.10	-0.11	-0.11	0.24	-0.20	-0.22
B.S	0.40*	0.38	0.30	0.29	0.31	-0.31	0.35	0.36

Avail-K = Available K^+, Wsol-K =Water Soluble K^+, Exch-K = Exchangeable K^+, Diff-K = Difficulty K^+, K-Sup = K^+ Supply, K–Res = K^+ Reserve, Resi-K = Residual K^+, Tot-K = Total K^+; * Significant at $p < 0.05$, ** Significant at $p < 0.01$. Ex.A = Exchangeable Acidity, O/C = Organic Carbon, O/M = Organic Matter, Ca^+ = Calcium, Mg^+ = Magnesium, K^+ = Potassium, Na^+=

Table 5: Correlation coefficient between potassium forms

	Avail-K	Wsol-K	Exch-K	Diff-K	K-sup	K-res	K-resi	Tot-k
Avail-K	-							
Wsol-K	0.98**	-						
Exch-K	0.41*	0.22	-					
Diff-K	0.39*	0.28	0.64**	-				
K-Sup	0.41*	0.29	0.69**	0.99**	-			
K-Res	0.41*	0.36	0.37	0.63**	0.63**	-		
K-Resi	0.04	0.01	0.13	-0.09	-0.09	-0.27	-	
Tot-K	0.13	0.09	0.22	0.04	0.04	-0.05	-0.27	-

Avail-K = Available K^+, Wsol-K =Water Soluble K^+, Exch-K = Exchangeable K^+, Diff-K = Difficulty K^+, K-Sup = K^+ Supply, K–Res = K^+ Reserve, Resi-K = Residual K^+, Tot-K = Total K^+; * Significant at $p < 0.05$, ** Significant at $p < 0.01$.

0.51* and 0.45*, respectively) in soils (Table 4). Residual-K was found to be positively and highly significantly ($P < 0.01$) correlated with only soil total K (r =0.93**).

Table 6: Regression equation for available potassium and other forms of potassium

Parameters	Regression equation	r2
Avail-K Vs Exchangeable-K	y = 0.776x + 0.002	0.86
Avail-K Vs Difficultly-K	y = 4.855x - 0.356	0.42
Avail-K Vs K-Supply	y = 5.63x - 0.353	0.49
Avail-K Vs K-Reserve	y = 6.624x - 0.575	0.17
Avail-K Vs Residual-K	y = 9.808x + 11.04	0.02
Avail-K Vs Total-K	y = 16.43x – 10.47	0.05

Table 7: Percentage of exchangeable potassium to Available potassium in the soil

	Exchangeable K	Available K	(%)
Crest	1.28	1.57	81.5
Upper slope	1.14	1.41	80.9
Middle slope	1.45	1.83	79.2
Lower slope	1.03	1.45	72.0
Valley bottom	1.38	1.75	78.5

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Geographic Information System (GIS)-Based Digital Mapping of Soil Properties for Arable Agriculture in Ike-Bunu, Kogi State

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Abstract
Geographic information system (GIS) technology is increasingly applied in mapping of soil properties and land attributes, as it hastened decision making processes. This study assessed and mapped the potentials of a 21,692.51 ha parcel of land in Ike-Bunu, Kogi State, using soil/land attributes and evaluated their potential for arable agriculture. Six mapping units were delineated, namely: MU-1 (3391.35 ha), MU-2 (1689.65 ha), MU-3 (1549.66 ha), MU-4 (5065.96 ha), MU-5 (4905.390 ha) and MU-6 (hilly terrain, 6,977.03 ha) based on soil properties and terrain analysis. Five (5) profile pits were dug across the study site and described according to FAO guidelines. Soil samples were collected from each identified genetic horizons for laboratory analysis. GIS database was generated for selected soil physical and chemical properties using ArcGIS 10.3 application. Results showed the dominant textural class of the soils was sandy loam underlain by sandy clay loam. Values of bulk density (BD) ranged from 1.04 to 2.35g cm^3. Soil pH rated from strongly acidic to neutral (pH 4.8 to 6.9). Organic carbon (OC) was low (2.14 to 8.57 g kg^{-1}), total nitrogen (N) was high (0.84 to 2.66 g kg^{-1}), available P was low (1.0 to 8.0 mg kg^{-1}) and potassium content was low to high (0.02 to 1.68 cmol kg^{-1}). All the soil mapping units except the hilly terrain have potentials for arable agriculture. Hilly terrain could be used for agroforestry.
Keywords: Digital soil map, Agricultural potential, physical and chemical properties.

Introduction

Specific geographical features that have been identified in scientific investigations such as topography, river, soil and vegetation (Senhor, 2018), could also be reported in the form of a geographic information system (GIS). Soil and vegetation have strong mutual relationship. Soil provides nutrients, moisture, and anchorage to vegetation to grow effectively, while in turn vegetation provides protective cover for soil, reduces soil erosion, and helps to protect soil nutrients through litter accumulation and subsequent decay (Eni *et al.,* 2011). Soil, nevertheless is fundamental to ecosystem and agricultural sustainability and production because it supplies many of the main requirements for plant growth like water, nutrients, anchorage, oxygen for roots, and moderated temperature (Jamieson *et al.,* 2002, Van der Maarel 2004, Eni *et al.,* 2011). According to Marlborough District Council (2016), soils act as buffers to capture and store nutrients and microbes, treat a range of waste products, and store and filter water. Digital data acquired from sensors platforms such as Landsat, Google Earth have been used to increase landscape survey reliability (Steven, 1986). Before the introduction of Digital Elevation Models (DEMs), landforms were identified by means of interpretation of aerial photographs (Calogero *et al.,* 2015). Terrain information extracted from Digital Elevation Models (DEM) may be related to the specific morphometry of landforms or the general geo-morphometric characteristics of land surfaces (Steven, 1986). Web Soil Survey (WSS, 2017) provides soil data and information produced by the National Cooperative Soil Survey. The website was activated by the USDA Natural Resources Conservation Service (NRCS) and provides access to the largest natural resource information system in the world. Natural Resources Conservation Service (NRCS) has soil maps and data available online for more than 95 percent of the nation's counties in the USA and expected to have 100 percent in the near future.

Materials and Methods

The Study Site: The study site was an undeveloped forest land (21,692.51 ha) near Ike-Bunu in Kabba Bunu Local Government Area, Kogi State, Nigeria. The site lies between latitudes 8° 26' 1.642" N and 8° 14' 40.897" N, and longitudes 6° 29' 56.788" E and 6° 17' 56.78" E, on elevation ranging from 75 to 314 m above sea level. It lies within southern Guinea savanna vegetation zone. The annual rainfall is about 1338 mm which falls between May and November (Okoye *et al.,* 1995). The geology is basement complex rocks made up of migmatite-gneiss and granite-gneisses (KSMSMD, 2004; Ojanuga, 2006; Fatoye, 2018).

Siting of profile pits and ground thruthing: Satellite imagery (Space Shuttle Radar Topography Mission (SRTM)) of the site was used to extract digital geo-referenced data to plot the boundaries of the site and prepared the contour map used as base-line for the field work following the guidelines of Andrea *et al.* (2005). The vectorised imagery and the topography map aided the provision of land information system (LIS) used as a guide in siting five representative profile pits in the entire study site. Coordinates of each identified point was extracted using AutoCAD and ArcGIS 10.3 Application and data inputted into Hand-held Global Positioning System (GPS) device for purpose of ground thruthing and subsequent creation of database for each profile pit. Properties attributed to profile such as soil depth, texture, bulk density, pH, organic carbon, total nitrogen, available phosphorus, potassium formed part of the database using ArcGIS analysis.

Digital map of the site was produced using the geo-referenced laboratory data of the selected soil properties. Point Krigging was used in modelling and extrapolation of data obtained from visited spoints (profiles) to other areas not visited to produce digital map. The geostatistical interpolation followed the equation:

$$Z*(x_0) = \sum_{i=1}^{n} \lambda i Z(xi) \quad \text{..... (1)}$$

where $Z*(x_0)$ is the value to be predicted at the location x_0, $Z(x_i)$ is the known value at the sampling location xi, n is the number of locations within the search neighborhood used for the prediction, and λi is the kriging weight assigned to $Z(x_i)$ (Bhunia *et al*., 2016; Pravat *et al.,* 2016).

Profile description and sampling: Ten profile pits were dug to specification (2m x 1m x 1m) and described in the field according to FAO guidelines (FAO, 2006). One typical profile pit representative for each mapping unit was sampled for laboratory analysis. Soil sampling was collected sequentially from genetic horizons starting from bottom to top of the profiles.

Laboratory Analysis: The soil samples were air-dried, gently crushed in a mortal and sieved with 2 mm mesh and analysed for selected soil properties. Bulk density was also determined using clod method (ISO, 2017). Particle size distribution was by Bouyoucos hydrometer method (Bouyoucos, 1962). Soil pH (1:2.5) in water was determined using a glass electrode pH meter. Organic carbon content using the chromic acid oxidation procedure of Walkley and Black (Walkley and Black, 1934). Total Nitrogen was analysed by the micro-kjeldahl digestion method (Bremmer, 1996), followed by distillation and titration. Available phosphorus was extracted using Bray P1 method (Bray and Kurtz, 1945). Exchangeable potassium (K) was extracted with neutral 1N NH_4OAC solution. Potassium in the extract was determined using flame photometry (Thomas, 1982).

Results and Discussion

On the basis of the results of selected soil properties, six mapping units was digitally produced (Figure 1). The units were designated as MU-1 (3391.35 ha), MU-2 (1689.65 ha), MU-3 (1549.66 ha), MU-4 (5065.96 ha), MU-5 (4905.390 ha) and MU-6 (hilly terrain, 6,977.03 ha) based on soil properties and terrain analysis. Information regarding to soil properties are discussed below.

Physical properties: The results of selected physical properties are presented in Table 1. All mapping units have sandy loam texture underlain in some pedons by sandy clay loam. This could be attributed similar parent materials and environment in which the soils were developed. Bulk density of the topmost three horizons corresponding to root-zones ranged from 1.04 g cm^{-3} to 2.35 g cm^{-3}. Bulk density range of 1.00 to 1.70 is favourable for arable crop production (Allison. 2006). These results imply that MU-5 may not favour cultivation of deep rooted crops such as yam and cassava. According (Ahmed *et al.,* 2018; Usowicz *et al.,* 2013) soil bulk density is also a key value to estimate soil moisture content and total porosity.

Chemical properties: The results of selected chemical properties of the soils are presented in Table 2. Soil pH in an important soil properties that determine solubility and reaction of soil elements such as Al and Mn (John *et al*., 2018). The pH of the topmost three horizons ranged from 4.8 to 6.9 which according to Chude *et*

al. (2011) classification falls under strongly acidic to neutral. Soil pH range of 5.5 to 7.0 have been established as favourable for release of most crop/plant nutrients (Brady and Weil, 2002). On this basis, MU-3 which covers ….ha had surface pH of 5.1 may require liming as part of its management for optimal and sustainable crop production. The soil organic carbon ranged from 2.14 to 8.57g kg^{-1} and was low according to Esu (1991) fertility classification. Reasons for low organic matter might be due to the seasonal bush burning. Organic matter play important role in soil by binding soil mineral particles and provide exchange sites for nutrients. Management of these soils for intensive arable crop should put into consideration practices that will encourage return of crop residues back to soil. Total nitrogen was high (0.84 to 2.66g kg^{-1}) probably due to the land being under forest vegetation for ages. Available phosphorus ranged from 1.0 to 8.0 mg kg^{-1} which was low and potassium (K) ranged from 0.02 to 1.68 cmol kg^{-1} and was rated low to high. Low P in the soil units might be attributed to inherent properties of parent materials that formed the soils. Thus, Seid *et al.* (2017) suggested that to increase any economical agricultural production in such low P soils, will require raising of available P through various management practices such as application of organic manure or phosphorus-rich fertilizers. The soil units MU-1 and MU-2 with low K contents may require external K support through fertilizer application.

Conclusion

The study shows that, GIS-based mapping of soil properties could ease identification and mapping of suitable land for agricultural purposes in Ike-Bunu Kogi State. Important management information for the site could be deduced easily. Regarding to tillage operations, uniform treatment is possible. However, in terms of bulk density, MU-5 may affect choice of deep-rooted crops. Liming of the soils may not be required except in MU-3 with low pH. Potassium fertilization may form part of management of MU-1 and MU-2. In general, the study site has potentials for arable agriculture if these limitations could be amended.

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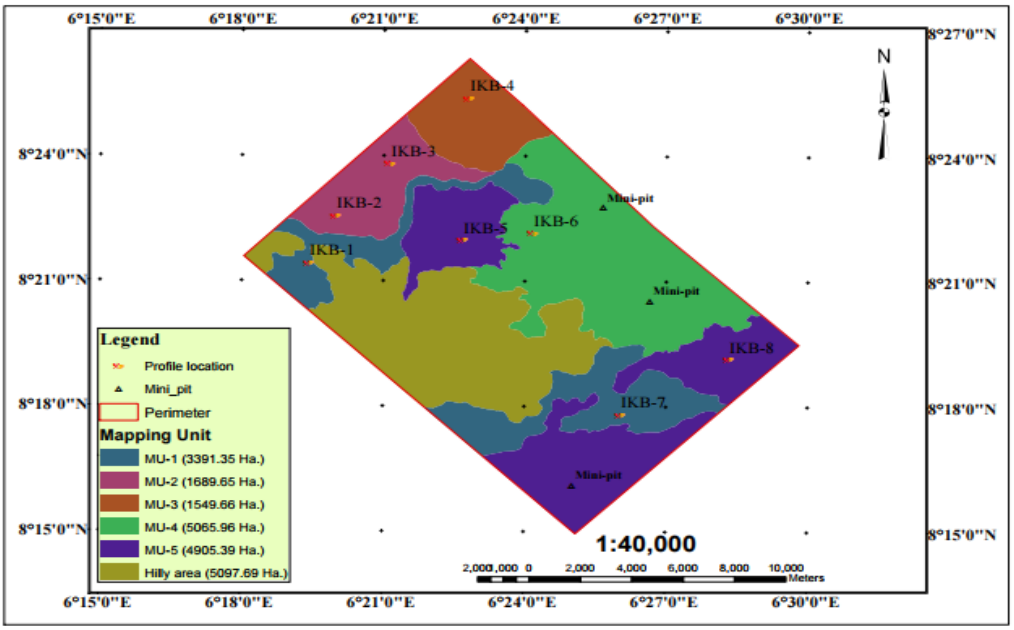

Figure 1.0: Map Showing Major Soil Type of the Study Site

Table 1: Physical properties of the soils of Ike-Bunu

Soil Mapping Unit	Soil Depth (cm)	Sand	Silt	Clay	Textural class	BD
			(g kg^{-1})			(g cm^{-3})
MU-1	0 – 7	741	65	194	SL	1.04
	7 – 29	691	75	234	SCL	1.11
	29 – 60	761	55	184	SL	1.25
	60 – 69	621	55	324	SCL	1.32
	69 – 92	601	85	314	SCL	1.24
	92 – 174	561	105	334	SCL	1.27
MU-2	0 – 9	771	45	184	SL	1.39
	9 – 24	781	45	174	SL	1.27
	24 – 50	761	55	184	SL	1.12
	50 – 121	631	75	294	SCL	1.12
	121 – 135	611	115	274	SCL	1.81
	135 – 159	571	125	304	SCL	1.20
	159 – 195	591	125	284	SCL	1.14
MU-3	0 – 10	781	45	174	SL	1.18
	10 – 33	741	65	194	SL	1.42
	33 – 67	731	55	214	SCL	1.17
	67 – 190	661	35	304	SCL	1.95
MU-4	0 – 9	791	45	164	SL	1.50
	9 – 24	771	65	164	SL	1.04
	24 – 37	741	85	174	SL	1.08
	37 – 60	761	55	184	SL	1.03
	60 – 111	631	95	274	SCL	1.04

	111 – 147	-	-	-	-	-
MU-5	0 – 6	711	105	184	SL	1.17
	6 – 10	671	95	234	SCL	1.10
	10 – 22	601	105	294	SCL	2.35
	22 – 61	631	65	304	SCL	2.15
	61 – 72	-	-	-	-	-
	72 – 82	581	105	314	SCL	1.10

Note: SL = sandy loam, SCL = sandy clay loam, BD=Bulk density

Table 2: Chemical properties of the soils of Ike-Bunu

Soil Mapping Unit	Soil Depth (cm)	pH (H_2O)	OC (g kg^{-1})	N	P (mg kg^{-1})	K (cmol kg^{-1})
MU-1	0 – 7	6.3	6.86	2.66	2	0.02
	7 – 29	5.6	6.43	1.68	1	0.09
	29 – 60	5.4	5.79	1.40	2	0.07
	60 – 69	5.4	4.71	1.96	1	0.04
	69 – 92	5.5	5.36	1.40	1	0.02
	92 – 174	6.2	4.29	1.82	1	0.11
MU-2	0 – 9	5.8	4.93	1.54	3	0.07
	9 – 24	5.6	5.14	1.12	2	0.07
	24 – 50	5.2	4.50	1.96	2	0.07
	50 – 121	5.5	3.86	2.10	1	0.12
	121 – 135	5.6	3.43	0.98	1	0.14
	135 – 159	6.1	2.57	1.26	1	0.07
	159 – 195	6.2	3.21	1.68	3	0.05
MU-3	0 – 10	5.1	5.57	1.40	6	0.20
	10 – 33	6.4	8.57	1.96	3	0.32
	33 – 67	6.3	4.71	2.24	3	0.22
	67 – 190	5.2	4.93	1.26	3	0.22
MU-4	0 – 9	6.2	3.64	1.68	3	0.42
	9 – 24	6.0	8.57	1.12	2	0.13
	24 – 37	5.7	4.93	1.40	2	0.70
	37 – 60	5.3	5.36	0.84	1	0.10
	60 – 111	5.0	4.29	1.54	1	0.08
	111 – 147	-	-	-	-	-
MU-5	0 – 6	5.6	5.14	1.40	3	0.33
	6 – 10	5.4	5.36	1.12	3	0.88
	10 – 22	5.4	8.14	0.84	3	0.56
	22 – 61	5.5	8.79	1.96	2	0.56
	61 – 72	-	-	-	-	-
	72 – 82	6.2	7.50	1.26	1	2.08

Note: OC = organic carbon, N = total nitrogen, CEC = cation exchange capacity

ASN 53rd Annual Conference Proceedings (Sub-Theme: Soil Conservation, Fertility and Water Mgt.)

Greenhouse Assessment of N, P and K Content of Maize as Influence by Integrated Soil Management Practices

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Abstract
The study was designed under greenhouse experiment to assess the effect of soil compaction, Bradyrhizobium inoculation in soybean-maize-based cropping systems and nitrogen fertilizer applicationon on N, P and K content of maize. Compared to compacted soils, K was significantly higher in uncompacted soils of 1.31 Mg m^{-3} bulk density, with percent differences of 14.02 %. Contents of N obtained under continuous sole maize was significantly lower than others pots with Bradyrhizobium inoculated or uninoculated soybean-maize cropping systems with difference 14.71% for rotation inoculated, 7.56% for rotation uninoculated, 10.50% for intercrop inoculated and 2.94% for intercrop uninoculated. Similar trend was found in P and K concentration in maize shoot dry matter between continuous sole maize and other cropping systems. The results also showed an increase in N, P, and K concentration with N levels of application and a decrease after 80kg N ha^{-1}. The results show that N fertilizer application in combination with compaction influence N, P and K content of maize. This is significantly supported by inclusion of bradyrhizobium inoculation in soybean-maize-based cropping systems which in turn would promotes soil productivity.
Keywords: Greenhouse, Integrated, Soil, Management

Introduction

Maize (*Zea mays* L.) is the third most important staple food crop in the world after wheat and rice but in term of productivity, it ranks first followed by rice and wheat. This is not only an important food and fodder crop for human being and animals but also is being used for manufacturing of many industrial products. Therefore, owing to its various uses, maize is known as 'Queen of cereals' (Rakesh *et al*., 2016). Therefore, the need for increasing its production has become a global priority in context of its multidimensional uses. This crop has tremendous genetic variability, which enables it to thrive in all kinds of climates but thrives best in a warm climate (rainy season) therefore, grown all agro-ecology in Nigeria.

Use of repeated heavy machinery at the same depth over the years are the common practice adopted by the farmers of Northern Savanna under intensive cropping system hence the soil undergone many physical disturbances to obtain optimum output. The problem of soil compaction is one of the major agricultural and environmental concerns in modern day intensive agriculture and land use in general and has been recognized as a major physical threat to soil fertility throughout the world (Soane and Van, 1994; Rakesh et al., 2016).

The over use of machinery especially passing of heavy tractors has been recognized as the major anthropogenic cause of soil compaction (Saffih- Hdadi *et al.,* 2009) especially in poorly drained soil hence soil compaction is one of the major abiotic problems in heavy texture soil for maize crop production (Rakesh et al., 2016). Many studies have shown that plant growth and productivity decrease with soil compaction by reducing the root enlargement, restricting oxygen, water and nutrient supply. Low hydraulic conductivity caused by compaction may induce water shortage to plant growth especially for high transpiring plants. The restrictions to plant growth in compacted soil are also caused by oxygen deficit. Most of the farmers are

aware of compaction problems, but the significance is often underestimated. Furthermore, recovery and amelioration of compacted soil could be slow, if it occurs. The depth of fertilizer placement is an integral part of effective nutrient management (Xuejun *et al.,* 2006) and crop growth because placement depth strongly influences the subsequent mobility and availability of nutrients hence reduces yield remarkably. Moreover degree of compaction also strongly influences the mobility and availability of nutrients. Most research over the year have placed emphasis on just distance of the band to the neglect of depth of placement and therefore, varying the depth of fertilizer placement together with distance of placement from the plant will provide an in depth knowledge with regard to the appropriate depth of fertilizer placement for optimum plant usage. Correct fertilizer placement ensures minimal losses due to leaching, vaporization and complex formation which may render the nutrient unavailable to the intended crop (Tisdale *et al*., 2003) and consequently improves the nutrient use efficiency and encourages higher yield (Rakesh *et al.,* 2016). The study aimed to assess nutrient concentration of maize as influenced by different degree of soil compaction and N fertilizer application in soybean-maize-based cropping systems.

Materials and Methods

Greenhouse experiment was carried out at the Department of Soil Science, Faculty of Agriculture, Ahmadu Bello University, Samaru, Nigeria. The Greenhouse is located within longitudes 11° 11' N and latitudes 007° 37' E. The bulk soils used for the experiments were taken from 6 points at 0-15 cm depth (top soil) using spade from the field where the field trial was conducted. The samples were bulked, air-dried and sieved with a 5 mm sieve in readiness for compaction process. The treatments consisted of two levels of compaction (compacted and uncompacted soils) as main plot. A total of 120 pots (PVC) with diameter of 15 cm and 52 cm height were filled with prepared bulked soil of about 15 % moisture content to a predetermined depth (50 cm) for compaction process. Approximately 8.1 kg of soil at 15 % water content was placed in PVC cylindrical pots, and the bulk density was 1.31 Mg m^{-3} in the non-compacted pots. The compacted pot was prepared by packing soil in a Proctor hammer (5 cm i.d., 30 cm drop height, 10.4 kg weight) in three layers by giving a sufficient number of blows using a flat-bottom hammer to reach the target bulk density (approximately 1.50 Mg m^{-3}). Soil bulk densities were determined by the core method (Blake and Hartge 1986). A handy penetrometer gauge was used to obtain uniform penetration force of 2.5 kPa in all the compacted pots. The two bulk densities used for the uncompacted and compacted soils were based on established bulk density range of 1.39 to 1.50 Mg m^{-3} for soils of Samaru, Northern Guinea savanna of Nigeria (Oikeh *et al*., 1998). Continuous maize, maize-inoculated soybean rotation, maize-uninoculated soybean rotation, maize-inoculated soybean intercrop and maize-uninoculated soybean intercrop and nitrogen fertilizer rates of 0, 40, 80 and 120 kg N ha^{-1} were sub plots. Pots were arranged on a bench in the greenhouse according to a randomized complete block design with three blocks (i.e. each block contained all 15 treatments × 2 soil compaction× 4 rhizobium inoculation and nitrogen application rates x 3 replicates).

Two sets of experiments were conducted and terminated at eight weeks respectively. In the first experiment, soybean seeds were divided into two, one part was inoculated with commercial rhizobium inoculants, Legume-fix at 400 g ha^{-1} (inoculated soybean) while remaining seeds were not inoculated with any rhizobium inoculants (uninoculated soybean) as shown in Fig. 1. Before inoculation the soybean seeds were sterilized, as reported by Vicent (1970). The peat-based inoculants (Legume-Fix) were applied directly on the seed with some quantity of liquid gum arabic as adhesive to coat the seeds plus little quantity of water and gradually stirred with stick to enhance uniform coating as contained in the user guide produced by the company. The inoculated seeds were allowed to stay for about 10-15 mns under shade to avoid effect of direct sun light and for air-drying before planting. Both maize and soybean seeds were sown on the same day in all the pots but uninoculated soybean pots were sown first to avoid contamination. Four seeds were sown per crops in all the pots and thinned to two per stand (1:1 per stand for intercrop, 2:0 per stand for rotation and 2 per stand for continuous maize) at 10 days after sowing. The first set of greenhouse experiment was established mainly to create enabling soil environment to carry out effect of the following rhizobium inoculation in maize-soybean cropping systems; continuous maize, maize-inoculated soybean rotation, maize-uninoculated soybean rotation, maize-inoculated soybean intercrop and maize-uninoculated soybean intercrop on soil microbial biomass C and N in second set of greenhouse. The first set of the experiment was terminated at 8 weeks after sowing. The crops (maize and soybean) were harvested by cutting of the shoot system at their base without causing any disturbance to the soil and root system within the pots. The second set of the experiment

commenced at 2 weeks after first experiment was terminated (harvested). In second set experiment, all the 120 pots both compacted (60 pots) and uncompacted (60 pots) soils were sown only with 6 seeds of maize without soybean and thinned to 2 per stands at 10 days after sowing. The experiment was also terminated at 8 weeks after sowing.

Phosphorus (single supper phosphate; SSP) and potassium (Muriate of potash; MOP) fertilizers were applied to all the pots planted at the rate of 60 kg P_2O_5 ha^{-1} (1.45 mg kg^{-1} soil) and 60 kg K_2O ha^{-1} (0.44 mg kg^{-1} soil) at planting, respectively. But the sole soybean used for rotation received 40 kg P_2O_5 ha^{-1} (2.50 mg per kg soil) and 60 kg K_2O ha^{-1} (0.75 mg kg^{-1} soil) and no N fertilizer was added to the soybean in intercrop pots. The pots containing maize in both sets of experiment received N (urea) fertilizer application at the rates of 0 kg N/ha (0 mg kg^{-1} soil), 40 kg N ha^{-1} (3.26 mg kg^{-1} soil), 80 kg N ha^{-1} (6.52 mg kg^{-1} soil) and 120 kg N ha^{-1} (9.78 mg kg^{-1} soil), which was shared into two: first and second applications were at 2 and 6 weeks after sowing, respectively. Fertilizer application was done by band placement method and late in the evening in both sets of the experiment

Soil and plant sampling and Laboratory Analysis

Composite soil sample was taken from the bulk soil before pots experiment and used for initial soil analysis following standard procedures (IITA, 1989). The soil was sandy loam in texture with the following properties: pH (Water), 5.40; Corg, 5.50 g kg^{-1}; Ntot, 0.46 g kg^{-1}; available P (Bray 1-P), 9.14 mg kg^{-1}; exchangeable cations (cmolkg^{-1}) of Mg^{2+}, 0.36; Ca^{2+}, 0.80; K^{+}, 0.15; and Na^{+}, 0.28; exchangeable acidity (cmolkg^{-1}), 1.08; extractable micronutrients (mgkg^{-1}) of Cu, 3.36; Fe, 71.68; Zn, 2.94 and Mn, 96.52, Bacteria; 8. 50 x 10^6 cfug^{-1} soil, fungi; 3.44 x 10^6 cfug^{-1} soil, MB-N; 16.98 mg kg^{-1}, MB-C; 188.68 mg kg^{-1} and C_{mic} : $N_{mic;}$ 11. All plants in each of the pots at 8 weeks after sowing were cut at ground level, bagged and oven dried. The shoot were ground in a hammer mill, passed through a 0.5 mm sieve and stored at -5 0C in bags for analysis of nitrogen content by micro-kjeldahl digestion method (Bremner and Mulvaney, 1982), phosphorus by the Bray 1 method (Olson and Sommers, 1982) and potassium was estimated using Flame Photometry (FP) (Jackson, 1958).

Statistical analysis

Data collected were subjected to analysis of variance (ANOVA) using the mixed linear model MIXED Procedure of SAS, Institute Inc., (2009). Duncan's multiple range test procedures was used when the F-cal of the ANOVA for each variable was found to be significant and their interactions were compared by computing least square means and standard errors of difference (SED) at 5 % level of probability

Result and Discussion

The results on concentration of total nitrogen (TN), phosphorus (P) and potassium (K) of maize under greenhouse experiment are presented in Table 1. No significant difference was found between soil compaction on TN and P, except for K concentration in maize shoot. The result indicated that uncompacted soil had higher concentration of TN and K in shoot than compacted soil. Compacted soil, however, recorded a higher concentration of P in maize shoot dry matter yield. The percentage difference between soil compaction on K concentration in maize shoot was 14.02%.

Similar results have been reported by many studies (Singh *et al.,* 2015 and Rakesh *et al.,* 2016). They concluded that decreased nutrient uptake with increasing soil compaction was due to decreased root growth, lower root surface for absorption of water and nutrients, increase in the length of mass flow and diffusion for nutrient movement. The effect of cropping systems on N, P and K concentrations of maize shoot are presented in Table 1. There was a significant difference ($P < 0.05$) between the cropping systems on N, P and K concentration in shoot dry matter of maize. The results also indicated that inoculated soybean-maize rotation had the highest value, followed by maize-inoculated soybean intercropping; while the least value was obtained for continuous sole maize pots. The percentage difference between sole maize and other cropping systems with regard to N concentration in maize shoot dry matter was 14.71% for rotation inoculated, 7.56% for rotation uninoculated, 10.50% for intercrop inoculated and 2.94% for intercrop uninoculated. Similar trend was found in P and K concentration in maize shoot dry matter between continuous sole maize and other cropping systems.

Pots fertilized with 120kg N ha^{-1} had significantly higher TN concentration($p<0.05$) in shoot dry matter of maize than other N levels of application, including pots with 0 kg N ha^{-1} (Table 1). The same trend was found for P and K concentration. The results also showed an increase in N, P, and K concentration with N levels of application and a decrease after 80kg N ha^{-1}. The data on control pots revealed consistent lower values of N, P

and K concentration, which reflected the observations made from the field experiment. Similar, observation was made by Metin *et al*. (2011) that fertilizer application increases both leaves and shoot tissue N, Ca, Mg, P, K, and Mn but decreases tissue Fe, Zn, and Cu content in maize. The concentration of plant N, P and K nutrients measured was generally within the critical levels established by Vavlin *et al.,* (2005). The results also showed increases in N, P, and K concentration with N levels of application, and decreases after 80 kg N ha^{-1} for P and K. This suggests that additional N above 80 kg N ha^{-1} might result in luxurious consumption with less benefit to plant.

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Fig. 1: Soybean seeds at left hand before inoculation and inoculated soybean seeds at the right hand after inoculation

Table 1: Effect of soil compaction, Cropping system and N fertilizer on N, P and K concentration in maize shoot

	Nutrient concentrations in maize shoot (%)		
	N	P	K
Soil compaction (SC)			
Compacted soil	2.37	1.92	4.28b
Uncompacted soil	2.41	1.86	4.88a
SE	0.06	0.08	0.16
Cropping system (CS)			
Sole maize	2.38b	2.15b	3.83b
Rotation-inoculated	2.73a	3.94a	4.80a
Rotation-uninoculated	2.56ab	3.79a	4.13ab
Intercrop-inoculated	2.63ab	3.86a	4.71ab
Intercrop-uninoculated	2.45ab	3.82a	4.70ab
SE	0.11	0.13	0.30
N rate (kg ha^{-1}) (NR)			
0	0.68c	0.73c	1.46d
40	2.39b	2.97b	3.24c
80	2.69a	3.96a	4.84a
120	2.81a	3.91a	4.19b
SE	0.13	0.12	0.27
Interaction			
SC*CS	NS	NS	NS
SC*NR	**	**	NS
CS*NR	NS	NS	NS
SC*CS*NR	NS	NS	NS

N = Nitrogen, P = Phosphorus, K = Potassium, NS = Not significant

ASN 53rd Annual Conference Proceedings (Sub-Theme: Soil Conservation, Fertility and Water Mgt)

Nutrient Mapping for Improved Cotton *Gossypium Spp* yield and Fiber Quality Using Geographic Information System

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Abstract

The neglect of spatial variations existing within fields in this era has led to high inefficiencies of production inputs and reduction of farmer profit. Geographic Information system through plant and soil nutrient mapping provides a helpful tool for assessing soil nutrient status, its impact on cotton yield and fiber quality and taking managerial decisions to boost yield and sustain the soil.This study was conducted to find out the spatial variation of soil macronutrients and evaluate the impact of Potassium (K) fertilization on yield and quality of some high yielding cotton lines and crosses. Six soil samples were taken from different zones of the field, for soil analysis prior to planting. The trial was set in triplicate using a randomized complete block design in 2018 growing season. Three levels of Potassium muriate was adopted (0, 30 and 45kgK/ha) and imposed 3 weeks after sowing (3 WAS).Results showed significance for plant height, days- flowering and micronaire, differential performance of same genotypes with different K treatments at 5% level of significance. As K level increased, there was reduced boll shedding, leaf bronzing, increased boll/plant, plant height, boll weight and plant yield/plant. Spatial autocorrelation of soil properties revealed randomness for all soil nutrients and indicated a negative Moran's Index of 6.7% for phosphorous, a spatial dependence of 28.5% for magnesium, 41.2% for total nitrogen and 44.9% for calcium respectively. Only potassium had a positive Moran's index of 0.08 (8%). All soil nutrients as in the statistical analysis were also spatially correlated. Spatial autocorrelation of yield and fiber properties indicated a negative Moran's I for seed cotton yield/plant, lint yield/plant and length (25.5%, 23.5% and 95.2%). Boll weight and micronaire had positive Moran's I of 13.8% and 11.5% each. Overall the soil, yield and fiber properties showed high to medium spatial dependence.

Introduction

The cotton crop has been used as a fiber for more than 7000 years. Unlike fossil based fibers, cotton is sustainable, renewable, biodegradable and carbon neutral. It can also be used without any consequential effect on the environment and thus, making it an excellent choice as an environmentally friendly fiber throughout its entire product life cycle (Zhang et al., 2017). On a global scale, cotton is planted over 31.8 million hectares of land with an annual production of 24.57 million tons (MT) (NCC, 2017; ICAC, 2017)). In Africa, the major producers of cotton are Burkina-Faso, Mali, Benin and Cote d'voire. Nigeria was ranked the 23rd largest cotton producer in the world and the 6th in Africa, producing only 1.5% of the global output in the year 2017 (FAOSTAT, 2017).

The modern day demand and preference pricing of high quality cotton by textiles and the international market has sprouted the need to breed for cotton varieties that are not only high yielding but possess longer lengths with micronaire of acceptable range. Micronaire is one of the two most important fiber characteristics for international cotton classers and spinners. Acceptable micronaire and longer cotton fibers will invariably meet the farmers' profit margin and help processors produce yarns of high quality without operational defects. To ensure ditto, it is necessary to manage both genetic and environmental factors affecting yield and fiber quality. A major environmental factor hindering the production of quality cotton in Nigeria and worldwide is nutrient deficiency and improper fertilization (Elms and Green, 1998; Bradow and Davidonis,

2000; Johnson et al., 2002; Wang *et al*., 2017, Zeeshan *et al*., 2017). Most unfortunately, amongst cotton farmers of this region are the practice of blind/uniform fertilizer application and the neglect of field spatial variability. Several studies have shown that soil nutrients vary spatially in fields (Gaston et al.,2001; Oosterhuis et al., 2013, Wang et al., 2017), and the neglect of this fine-scale variations existing within farmers' fields can lead to the high inefficiencies of production inputs and reduction of farmers' profits (Stewart *et a*l 2005).It is therefore necessary to create awareness and map the needs of specific farm sites and crop requirements for maximized use and profitability in Nigeria in order to help revive the lost industry. In cotton production, macronutrients such as nitrogen (N), magnesium (mg), potassium (K), calcium (Ca) and phosphorous (P) has to be available in desired quantities at various growing stage of the crop for healthy growth, high yield and desired quality. There are various interpolation tools to display nutrient status of soils with geographic information system (GIS). A number of studies on soil fertility mapping have been documented (Ravikumar *et al*., 2004; Ismail, 2009; Adekayode et al., 2014, Zeeshan et al., 2017; Bhusal et al.,2018) and Kriging interpolation was found most accurate in nutrient mapping. Interpolation is simply a procedure used to predict values of samples at unknown locations. It is based on the principle of spatial dependence or spatial autocorrelation, which measures the degree of dependence between near and distant objects. Chances are that *everything is related to everything else, but near things are more related than distant things* (Tobler's first law of geography). At a certain distance, autocorrelation levels off and becomes independent. This means there will be no more spatial relationship between the closeness of data. Kriging is a technique of spatial interpolation and also, a type of regression that gives least square estimates of data (Remy et al., 2011). The degree of accuracy of kriging technique in the prediction of soil properties was explained in the report of Omran (2012) in the descriptive tools of semivariograms to characterize the spatial patterns of continuous and categorical soil attributes. The application of kriging technique had been premised on the principle that soil properties closer together would tend to be more alike than the distant points and the interpolation was a prediction made within the spatial extent of the measured locations.

Assessing localized impacts of Potassium that is found to be an exceptionally important nutrient in cotton production, (Wilde, 1971; IPNI., 2011, WEF, 2015), is another way of maximizing crop health and quality especially now that the frequency and severity of Potassium (K) deficiency have become widespread. It has been reported in most parts of Nigeria (Manu et al., 1999; Ekeleme*et al*., 2014; Shehu et al., 2015; Hengl et al., 2017). Potassium plays a major role in metabolism, growth, development, yield and fiber quality (Oosterhuis et al., 2015). An average cotton crop requires 105kg/ha with a peak of 3-5kg/ha/day (Mullins and Burmester 1990; Halevy 1976). Shortfalls in this requirement mostly lead to a deficiency in the crop at maturity and boll formation (Oosterhuis et al., 2013), thereby reducing seed cotton yield, lint yield, boll biomass, boll weight (Pettigrew et al., 2005;Hu et al., 2016b) and yield components such as number of bolls, seed number/ boll and seed index (100-cottonseed weight) (Pervez et al., 2005;Sawan et al., 2007a). Thus diagnosing K status will help to avoid its deficiency and excess application and thereby, minimizing production cost and maximizing yield and quality. This study was conducted to assess the spatial variation of soil macronutrients and evaluate the impact of Potassium (K) fertilization on yield and quality of some high yielding cotton lines and crosses.

Materials and methods

Study area

The research was conducted at the Institute of Agricultural Research (IAR) farm, A.B.U Samaru, Zaria. Samaru is located on latiude 11°11´N and longitude 7° 38´ E, at an altitude of 686m above sea level in the Northern Guinea Savannah ecological zone of Nigeria.

Materials

Three exotic lines; LST-6, MA-13 and CL-07 (from Texas A & M and Egypt respectively) and a premium quality cotton variety (SAMCOT-8) released by IAR, was crossed via Bi-Parental mating design in 2017, then evaluated alongside Parents and 2 Check varieties (SAMCOT 10 and SAMCOT 11). The trial was set in triplicate using a randomized complete block design. Three levels of Potassium fertilizer (Muriate of Potash) was adopted (0, 30 and 45kgK/ha) and imposed 3 weeks after sowing (3 WAS).

Soil Analysis

Six soil samples based on visual variations were taken from six grid points of the field for soil analysis prior to Trial Establishment. Soil sampling was done at depth of 0-15 cm with a 2.5-cm (1.0-in) diameter probe and locations of each sample point was recorded by global positioning system (GPS) receiver. Each composite

sample was air dried at room temperature, ground thoroughly to pass through a 2-mm (0.08-in) sieve, and analyzed for NO3-N, available P, Extractable K, CaCO3, soil PH and other physical properties.

Data Collection and Analysis

Data was taken on Plant Height, Days to 50% flowering, Bolls/Plant, Boll Weight, Seeds/Boll, Seedcotton Yield per plant, Lint Yield per plant, Fiber Length and Micronaire. In April 2019, mature SeedCotton was handpicked by row/genotype, hand-ginned, weighed and analyzed for Length (following the British standard, BS 4044, 1966). Length and micronaire were measured using the Comb Baer Sorter and Wira Cotton Fineness meter respectively. The comb sorter works on the end aligned principle. The fibers are arranged in the descending order of fiber length which forms an array diagram of which various properties related to fiber length are determined. The method is applicable to cotton samples of individual fibres having a maximum fiber length not greater in excess of 5cm. The Wira Cotton Fineness meter uses the air-flow method to determine micronaire. A test specimen of 5g of fiber is compressed to a fixed volume in an air permeameter. A current air is then drawn through the specimen and the diameter is obtained from the flowmeter.The SAS (2009) statistical software package was used to run analysis for descriptive statistics and Correlation. PROC CORR and Geoda 1.8 spatial software was used to compute pair-wise correlations between all soil properties, yield and fiber properties. Soil nutrients were classified following the method described by Wilding (1985). "soil nutrients with CV<15% were grouped as least variable, nutrients with CV value 15-35% were moderately variable while nutrients with CV value >35% were grouped as highly variable".

Spatial Nutrient Analysis and Mapping

The results of the soil nutrients was input in Microsoft Excel and saved as coma delimited (csv) file format. The data was joined and added as a layer on the study area map in ArcMap (10.6) in a Projected Coordinate Systems WGS 1984 UTM zone 32 N. It was then exported to a point Shape file through the Data/Export pathway. Using Geostatistical Analyst tool, soil and fiber datasets were log transformed to ensure the normalcy criteria for kriging. Ordinary kriging was then used to predict unknown values of soil nutrients concentration at unsampled locations based on the sample data. Point data of selected yield/ fiber property oil attributes were interpolated across the study site using the variousgeostatistical models(circular, exponential, spherical andgaussian models) and their spatial prediction were evaluated by choosing the ,model with lowest root means square. For every soil property the experimental variogram was calculated. Mapping of each predicted soil nutrients was carried out on ArcGIS 10.6 version. After krig mapping, soil nutrient and fiber yield and quality was classified into very low, low, moderate, high and very high following soil analysis criteria for soils. was carried out for selective soil parameters and macronutrients, their classes were defined as very low, low, optimum, high and The spatial dependence between samples was also determined by considering the relationship between the samples. Moran's index named after Patrick Alfred Pierce Moran, is a spatial statistic used to measure spatial autocorrelation, amongst geographically close samples, for each feature in a dataset to the mean value of the dataset.It is represented by this formula.

$$I = N \bullet \frac{\sum_i \sum_j w_{ij}\left(x_i - \bar{x}\right)\left(x_j - \bar{x}\right)}{\left(\sum_i \sum_j w_{ij}\right)\left(\sum_i \left(x_i - \bar{x}\right)^2\right)}$$

Where, where *N* is the number of cases, *xi* is the value of the variable at location *i*, *xj*is the value at location *j*(*i* ≠ *j*), *X* is the mean of the variable,and*wij*, a distance-based weight, is the inverse distance between locations *i*and *j*(1/*dij*).The autocorrelation analysis was carried out using Moran's Index (ArcMap) and cross validated with univariate Moran's I from Geoda software, and displayed as scatter plots. The Moran's score range from -1 (dispersed) to +1 (clustered). A value of 0, refers to random distribution Spatial dependence was then classified into; weak (ratio >75%), moderate (ratio 25-75%) and strongly spatial dependent (ratio <25%) (Attar et al., 2012).

Results and Discussion

Soil Properties (Univariate Statistics)

Soil property data from six sample grid points for 2018 cotton evaluation is presented in table 1. All soil properties with the exception of Calcium and Potassium showed a non-normal distribution. Soil PH, Calcium, Potassium and %Clay exhibited a slight positive skew as the mean of all but calcium were greater than the median. The rest of the soil properties displayed a negative skew which are asymmetric with lower values

tailing left. The negative coefficient of Kurtosis that is observed in all but Phosphorous, Cation Exchange Capacity and Organic Content are indicative of a flat tailed distribution and together these two coefficients (Skewness and Kurtosis) showed majority of the soil properties to be non-normally distributed. Coefficients of variation for the measured soil properties range from 3.8% for PH to 44%for potassium. The properties that displayed the greatest variability are; potassium, phosphorous, magnesium organic content, %clay and total nitrogen with CV 44.0, 28.8, 27.8, 21.3, 19.7 and 18.1 discretely. . Soil PH ranged from 6.7 to 7.3, while organic content ranged from 0.5 to 1. This result according to Wilding's (1985) grouping of soil property variation exhibits a moderate (15-35%) to highly (>35) spatial variability, in exception of soil PH, CEC and Ca which were least variable (<15%).Yield and fiber properties showed positive skewness for all but length which had a negative skewness and positive Kurtosis. All the other yield and fiber data were significantly different with CV 71.05 and 72.23 each. Boll weight and micronaire had a moderate CV while length possessed the least CV (12.56). A non_normal distribution was observed for the yield and fiber properties measured. The non-normal distribution of soil and yield/fiber data was a result of relatively high skewness and flat tailed kurtosis observed in most of the properties. Statistically, these two numerical measures of shape are used to test for normality. Skewnessnearer to zero with a kurtosis value ≥3 assures normality. With the high CV (44%) exhibited by K and moderate CV mentioned for p, mg, oc and %clay above, there is about enough nutrient to support cotton growth for moderate yield. However amendments to the low and moderate regions will boost yield in the study area.

Nutrient Status in soil

Ca, mg and oc which ranged from 2.6 to 3.5, 0.3to 1.0 and OC respectively were in the low range classification for soils derived from basement complex rocks in Nigeria (Table 2). K ranged from 0.3 to 0.9, while N showed a moderate range for the study area. The low K regions of the field are likely to produce low quality cotton due to increase demand of the nutrient during boll set and after first bloom, without which deficiency symptoms may result.

Soil PH, though least variable, satisfies cotton requirement of 6.5 to 7.5 near neutral PH range suggesting a balanced condition for cotton growth. However these cotton materials may not survive well outside the observed soil PH. These results are different from that of Johnson et al (2002) in their study Variability in Cotton Fiber Yield, Fiber Quality, and Soil Properties in a Southeastern Coastal Plain. They found a high variability, about 9.1% (PH) to 74% (P) variability in 1996 and 10% PH to 74% P for 1997 in a 0.5 ha field of a producer's field in Florence, with the data from the two years exhibiting non-normal distribution. Zeeshan et al., 2017 also reported non-normal soil datasets and similar high variations in soil nutrient results but pH was ranging from 7-8.5 with mean value of 7.72while conducting a research on Rice correlation and spatial variability of soil macronutrients with crop performance by using satellite and remote sensing indices for site specific agriculture in Chakwal region. In contrast, Wang et al (2017) reported a normally distributed soil and fiber data hence requiring no data transformation before semivarigram analysis.Lelago et al (2016) reported pH of the soil ranged from 4.6 to 8.5, indicting wide variation with status of strongly acidic to moderately alkaline.

Nutrient Mapping and Spatial Analysis

Spatial analysis of available P showed a range value of 19.69m from the best fit semivariogram model (spherical). This range is more than the average sampling distance of 11.17m, signifying the sampling interval to really capture the variability in phosphorous of the study area. Moran's I for P indicated random distribution, and displayed a 2% spatial dependence amongst samples on ArcGIS, and 2.57% on Geoda. This means P in the study area was highly spatially variable (0-25%) within the map extent. Following the soil analysis criteria in table 2, the krig map of available P (figure 2), shows the entire map area to be low in P (<5ppm). Available phosphorous (P) from table 1 above, varied from 13.75 to 28.8ppm with mean value of 20.8ppm. This indicates that the soil exhibit variability in P status. And this result is in line with that of Ismail et al (2014), who reported available P of 14ppm to be of good nutrient capacity. Lelago et al (2016), however reported varying levels of P from 1.0 to 74ppm, 0 to 267ppm and 1.0 to 209ppm respectively for their study sites in KedidaGamela, KachaBira and Damboya words of Ethiopia.

Calcium and Magnesium were also fitted to the spherical semivariogram model and showed range of 48.367m. The prediction map (figure 3) of Ca reveals a low calcium concentration (2-5**cmol kg^{-}1)**throughout the study area. Spatial autocorrelation of Ca and mg were both random with 48.33% and 31.3% Moran's I respectively on ArcGis. Geoda however showed 44.9% and 28.5% random distributions for Ca and mg. The

low calcium observed may be due to uneven soil moisture, overuse of fertilizer or transport protein. Cotton grown in this study area showed early seedling disease as a manifestation of low calcium in soil. Magnesium map displayed on figure 5 indicates glaring shortage of magnesium (0.009 to 0.06) as all regions in the map range below 1, the criteria for low magnesium in soil. This is closely matches the soil analysis result for mg which showed a low magnesium status (0.3-1**cmol kg**$^{-}$1). Magnesium is a constituent of chlorophyll acting as a regulator for various metabolic activities and phosphorous breakdown too. It's no surprise mg was low in the study site, due to its proximity to water and high humidity, mg is easily leached. With increased cation exchange capacity in soil mg losses can reduce. Also inorganic amendments and appropriate liming are the best fit for mg revival.

The prediction map of total nitrogen (TN) in figure 5, was best fitted to the circular semivariogram model. The range value for TN within which spatial correlation was confirmed is 48.367m. TN indicated a negative Moran's I with 51.56% spatial dependence. This value is within the range for moderate spatial correlation (25-75%). The predicted map revealed low to very low nitrogen in the study area (0.001113). This result is corroborated by those of Cornwinet al (2003) Lelago et al (2016) and Zeeshan et al (2017) whom have observed most soils with nitrogen level below the optimal r

ange. The observed low TN in the study area could be due to leaching and continuous cropping of cereals. Ismail and Junusi (2009), attributed low nitrogen to leaching, denitrification and volatization of N from soil. Cotton seedlings can do well under the observed TN concentration in the study area, but split amendments has to be provided before bloom to meet the crops peak demands. Cessation of cereal cropping and rotation of cotton with legumes may help revive the nitrogen to the area.

The krig and prediction map of K status is presented in figure 6. The exponential semivariogram model was found the best fit for exchangeable K. Following the soil analysis ratings in table 2, about 50% of map area revealed high K status (0.6-1.2), 40% revealed moderate K status (0.3-0.6) while the remaining 10% 0f map area have low K (0.2-0.3). Similar optimum to high and very high K concentrations results were reported by Lelago et al (2016) in agricultural lands of 3 woredas in Ethiopia. Autocorrelation reports on ArcGIS indicated a random 6% spatial dependence while Geoda shows 8% Moran's I. both results prove high (<15%) spatial dependence amongst K samples in the field. This finding is in line with that of Oosterhuis (2013) who reported spatial variability of K in farmers' field. Availability and uptake of potassium (K) by cotton plants is often complicated by many interacting components, two of the factors with predominating effect are the soil and plant characteristics involved. A third factor is improved fertilizer and management practices. These, can be used to modify the inherent characteristics of soils and plants involving K uptake. In general the presence of high organic content in the top soil tends to add K, while high CEC ensures binding and storage for later use. These findings are similar to those of Ismail et al (2014) in their study of soil fertility mapping: comparison of three spatial interpolation techniques, Kriging was affirmed the best interpolation method for soil mapping, PH, OM/OC and K were fitted to the exponential semivariogram and P to spherical model. They however found high PH, high p, low K level displayed by the maps. The precision nutrient variability study of an experimental plot in Muko Agricultural Research and Development Institute, Mukano, Uganda by Aded kayode et al., 2014 also corroborates these findings. All soil nutrients as in the statistical analysis were also spatially correlated.

Spatial autocorrelation of yield and fiber properties indicated a negative Moran's I for seedcotton yield/plant, lint yield/plant and length (25.5%, 23.5% and 95.2%). Boll weight and micronaire had positive Moran's I of 13.8% and 11.5% each. Given the z-scores attributed to these properties on spatial autocorrelation reports, the observed patterns do not appear to be significantly different from random. Overall the soil, yield and fiber properties showed high to medium spatial Dependence. The negative moran's index only shows the presence of small or large values greater than the differences in values of throughout the dataset of features that are geographically close. Only fiber length was (95.2) found to be weakly dependent (>75). This may be due to intrinsic factors such as genotypic effects. Fiber micronaire with Moran's I of 11.5% indicates the high spatial relationship of micronaire across different zones of the study area. It also implies different environmental variables affect micronaire value. Thus finding a strong correlationbetween soil properties and fiber micronaire can help attain cotton materials with desirable micronaire.

Analysis of Variance and Mean Performance for Potassium level experiments

The analysis of variance for the combined potassium levels of 10 traits of 3 cotton crosses/parents/checks evaluated in Samaru 2018 are presented in Table 2. The ANOVA for the combined effects of treatments of

treatments on traits were highly significant at (P≤0.01) for Boll/Plant (655.04), SeedCotton/boll (653.79), Seed Index (51.86), Lint Index (12.6), SeedCotton Yield/plant (892738.40) LintYield/plant (13035.28), and for Boll Weight (5.45). No significance was seen for PHT, D-50% F, GOT, length and Micronaire. High significant variation is also seen in genotype for all traits except boll/plant and seedcotton/boll. High significant variations are also seen in Rep(Trt) for traits but for PHT(515.15) D-50% FL (80), Seed Index (16.33) which are significant at (P≤0.05) and no significance shown for Lint Index, Seedcotton yield/plant, LintYield/plant, GOT and micronaire. A high significant difference in Trt*Genotype effect is shown only for micronaire (1.92) suggesting that micronaire variations exists among genotypes with respect to potassium treatments. This results are similar to those of Oosterhuisetal, 2013 & 2016; Morgan et al (2015) and Lokhande and Reddy (2015), all of whom found significant variations in cotton traits by potassium treatment effects.

Mean performance for the effect of 3 potassium levels on yield and fiber traits on yield and fiber quality traits of 3 cotton crosses is presented in Table 4.3. The number of days to 50% flowering showed significant differences among the parental genotypes as well as among the hybrids under the three K levels. It ranged from 87 days to 95 days, 86 days to 98 days and 87 days to 95 days under 0kgK, 30Kg and 45KgK conditions, respectively under 0kgK, the parent CL07 took the highest (95) number of days to 50% flower and the parent LST6, Ma13 and the cross Ma13*LST6 was the earliest. Under 30KgK, the parent Samcot 8 (98days) took the highest number of days to 50% flower and the parent LST6 was the earliest (86). Under 45KgK, the parent CL07 (93) took the highest number of days to 50%flower and the crosses Ma13*LST6 (85) and Sam8*CL07 (89) were the earliest. Boll/Plant showed no significant difference among the genotypes under the three K levels (Table 3). It however ranged from 23 to 27 bolls, 27 to 34 bolls and 30 to 35 bolls under 0Kgk, 30KgK and 45KgK respectively. Under 0 level K, parents LST 6, Ma13 and cross Ma13*LST6 had the least number of bolls/plant (23) while only cross Sam8*CL07 had the highest number of bolls/plant (27). The least number of bolls/plant was seen in cross Ma13*LST6 (30) and parents LST6 and Samcot 8 with 33 bolls/plant. Parent CL07 had the highest boll/plant in this level. Bolls weigh significantly different under the 3 Potassium levels with a range of 2.23 to 4.80. In Parent Samcot 8 (2.27) and cross CL07*Ma13 (2.23) had the least boll weights under 0KgK while parent Ma13 (3.20) and cross Ma13*LST6 (3.23) had the highest boll weights respectively. A similar pattern is seen for K level 30, where-in Parent Samcot 8 (2.87) and cross Sam8*CL07 (2.90) had the least boll weights. While parent LST6 (3.97) and cross Ma13*LST6 (4.80) hold the highest boll weights. As for k level 45, Samcot 8 (3.17) and cross Ma13*CL07 (2.30) had the least boll weights and parent LST6 (4.53) and cross Ma13*LST6 (4.37) had the highest boll weights respectively.

Fiber Length showed high statistical difference among genotypes, and the parental genotype with the shortest length under 0KgK level is CL07 (25.72), cross Sam8*CL07 also showed least length (26.32) while parent LST6 (33.22) and cross Ma13*LST6 (29.74) had the longest lengths respectively. In 30KgK level, parent Ma13 (25.02) and cross Sam8*Clo7 (25.82) showed the shortest length while parent LST6 (35.77) and cross Ma13*LST6 (31.37) again showed the longest fiber lengths. Under the 45KgK level, the parent and cross with shortest length are Ma13 (23.11) and Ma13*Clo7 (25.53) respectively. Parent LST6 (35.78) and cross Ma13*LST6 (29.49) again exhibit the longest length for this level. All the genotypes showed high significant variation for micronaire across the 3 potassium levels ranging from 2.74 to 5.72. Parent /cross with the least (finest) micronaire value under the 0KgK level is LST6 (2.74) and cross Ma13*LST6 (3.78) which is fairly fine. Parent Samcot 8 (4.68) and cross CL07*Ma13 (4.66) had a coarse micronaire texture. Under the 30KgK level, parent LST6 (3.10) and cross Sam8*CL07 (3.77) had a fine to fairly fine micronaire quality. While parent Ma13 (5.24) and cross Mai3*LST6 (4.03) had micronaire values that are fairly coarse to fairly fine respectively. A somewhat similar pattern is observed for 45KgK wherein parent LST6 (3.53) and cross Sam8*CL07 (3.09) exhibit fine fibers while parent CL07 (5.72) and cross CL07*Ma13 (3.60) had coarse to fairly fine fibers respectively. Fiber Micronaire is a measure of fiber maturity and fineness. It is generally considered that both too low and too high micronaire cotton should be avoided, as the former becomes is easily entangled around particlesof trash and leaf, thereby increasing the amount of good fiber lost. They are also break easily during processing. The later, which result of drought stress, water stress or too high yields causes problems in spinning as they are very coarse. Acceptable range of micronaire for upland cotton is 3.8-4.4. However, longer fiber species like the Barbadense do well under processing as long as they are mature. The genotypes with the acceptable micronaire range (3.8-4.2)under 30KgK are; crosses ma13*Lst6 and Samct8*Cl07 which had micronaire value 4.03 and 3.87 respectively. Under the same

treatment, Parent LST6, which is a long staple line had the highest fiber length with micronaire 3.1 which is in the fine range.

The result is similar to that of Ahmad et al (2018), in a foliar applied potassium enhances fibre quality, water relations and yield of cotton experiment he conducted to check the effect of different potassium (K) levels on water relations, fibre quality and yield traits of two cotton cultivars (FH-942 and FH-113) by applying Four levels of foliar potassium (0, 1, 1.5 and 2%). He found significant differences for fibre quality and yield parameters due to foliar applied K levels. But the foliar applied K @ 1.5% performed better than all other treatments for Maximum water (-1.08 and -1.11MPa), osmotic (-1.43 and -1.45 MPa) and turgor potential (0.64 and 0.56 MPa), fibre strength (28.12g /tex), fibre length (32.24 mm), fineness (6.22 micronaire), uniformity (54.60%) and fibre elongation (5.80%). at 40 and 60 DAS. The same K level showed maximum fibre strength (28.12g /tex), fibre length (32.24 mm), fineness (6.22 micronaire), uniformity (54.60%) and fibre elongation (5.80%), and also for yield related traits; sympodial and monopodial branches, bolls number, ginning outturn and yield. In contrast, Morgan et al, found increase in cotton growth parameters, plant height, yield and return on investement with increasein soil applied potassium via different methods across cotton growing belts of the USA in 2015.

Conclusion

Statistical analysis of soil data shows moderate and wide variations in the soil nutrients and properties. However, the spatial analysis and soil nutrient maps showed the study area to have low calcium concentration (2-5**cmol kg^{-1})**, glaring or very low magnesium (0.009 to 0.06 **cmol kg^{-1})**, and low total nitrogen, high phosphorous (27.2 to 28.3) and high potassium(0.85 to 0.92), hence a low to high spatial dependence. All the nutrients, soil properties and yield/quality properties studied showed spatial dependence at different levels but all were randomly distributed, ie there were dissimilar small and large values next to one another on the field. Phosphorous (2% and 2.57%) and potassium (6% and 8%) showed the highest spatial dependence in ArcGIS and Geoda. The PH range (6.5 to 7.5) found in the soils of the study area, was near neutral and it suggest a balanced condition for cotton growth. The observed low calcium, magnesium and Nitrogen in the study area were due to low organic activities, cation exchange capacity over cropping,bad farm practices and uninformed nutrient management. Specific organic or inorganic fertilizers of these nutrients should be applied to the study area. Other farm practices such as mulching, cotton strip plots may help boost nutrients availability, and as such nutrient map of study area should be put into consideration when making decisions to improve the site.

30KgK was found to perform better for parents, crosses and checks in days to 50% flowering, boll/plant, boll weight, length and micronaire. Parent Lst6 was found with the least number of days to 50% flowering (86 days), Boll/plant (33), heaviest boll weight, longest length 35.7 and finest fiber under the optimum K fertilization. Cross Ma13*LST6 (31.37) and Ma13*CL07 (27.85) also show long length and acceptable micronaire(4.03 and 3.87) and can be improved for further selection. Optimum K fertilization level (30KgK) should be adopted to further improve the quality of available cotton varieties.

The variability observed in nutrients and potassium levels in the study field can be delineated for site specific cotton management to enhance yield and quality.

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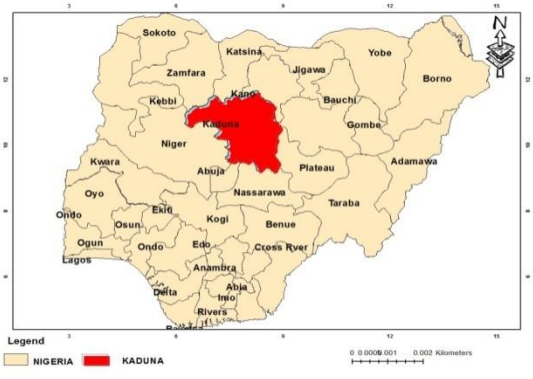

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Figure 1b: Kaduna showing Sabon_Gari LGA

Figure 1a: Map of Nigeria showing Kaduna state

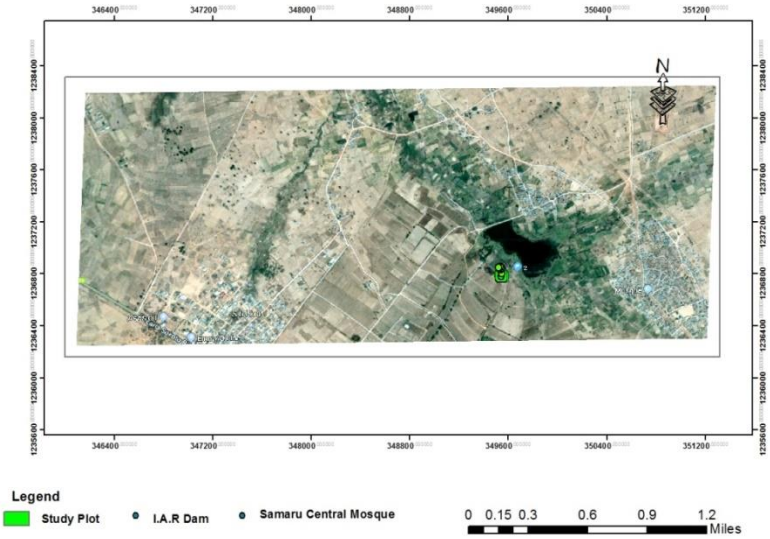

Figure 1c: Landsat Image of study area

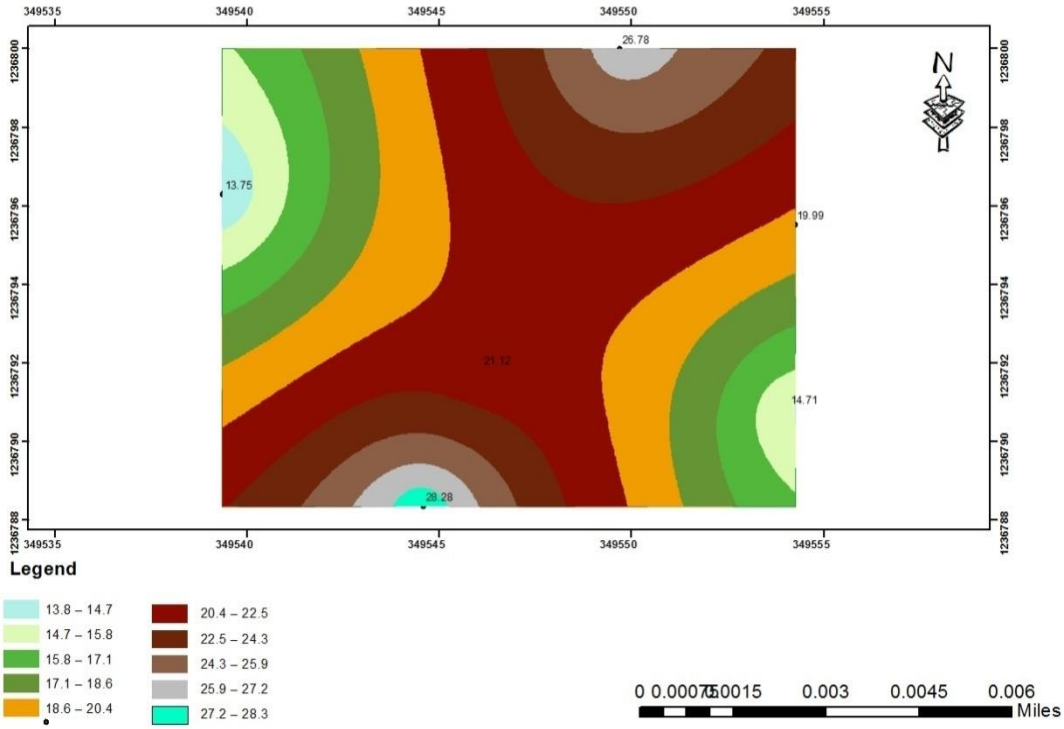

Figure 2: Prediction map of soil available phosphorous

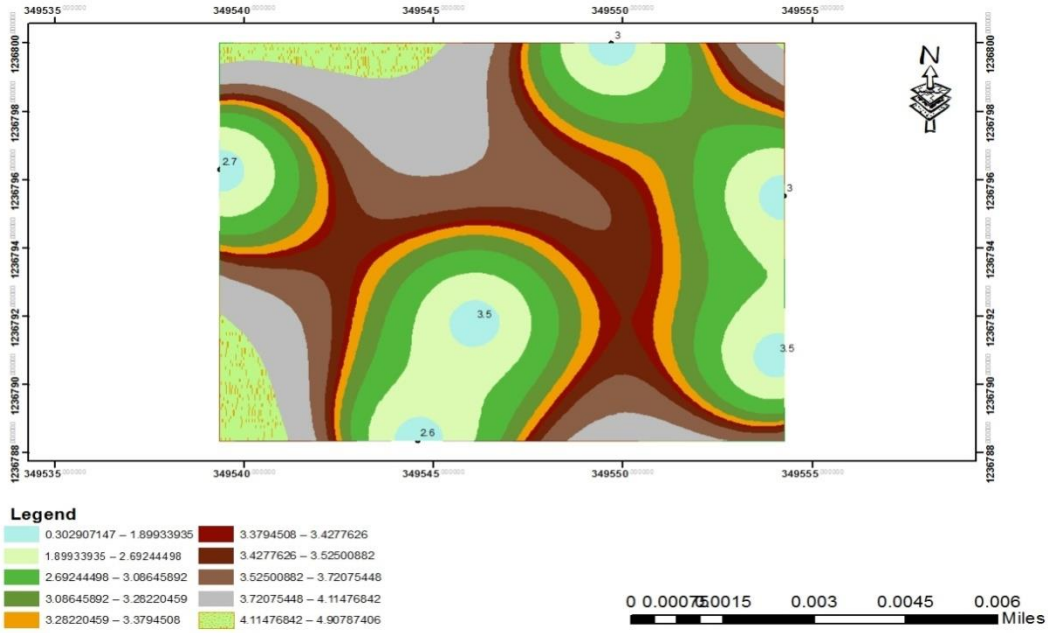

Figure 3: Prediction map of Calcium

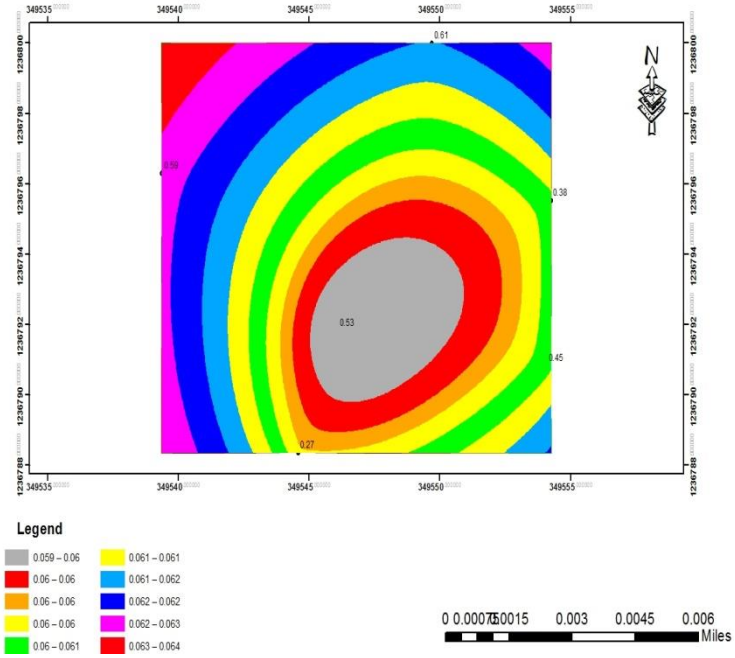

Figure 4: Prediction map of Magnesium

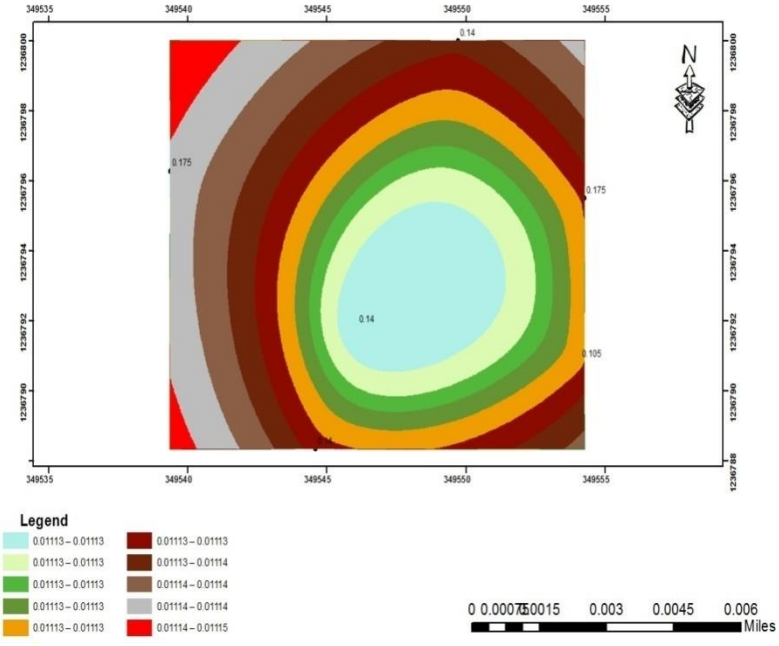

Figure 5: Prediction map of Total Nitrogen

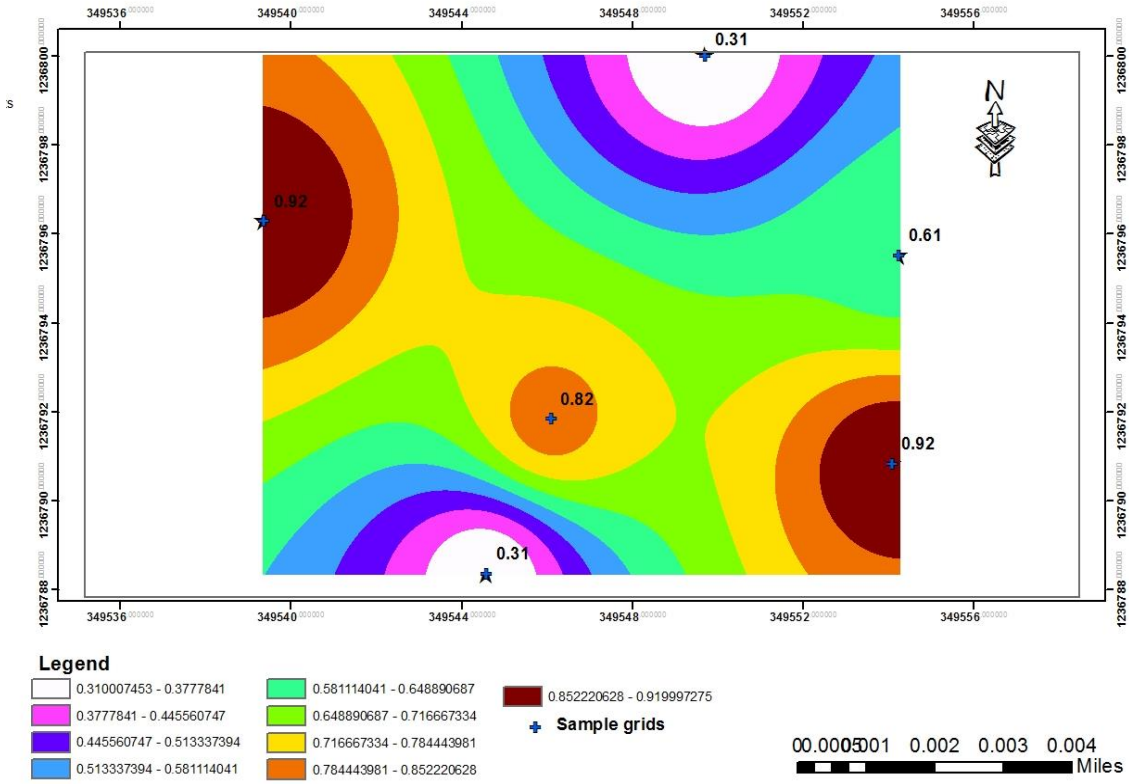

Figure 6: Prediction map of extractable Potassium

Table 1. Univariate Statistics of Soil, Yield and Fiber Properties for 2018 Cotton Field Experiment in Samaru

Variable	N	Mean	Minimum	Maximum	Median	Range	CV	Skewness	Kurtosis
Ca	6	3.1	2.6	3.5	3.0	0.9	12.6	0.3	-1.8
Mg	6	0.5	0.3	0.6	0.5	0.3	27.8	-0.6	-0.8
K	6	0.6	0.3	0.9	0.7	0.6	44.0	-0.4	-2.2
TN	6	0.1	0.1	0.2	0.1	0.1	18.1	-0.3	-0.1
AP	6	20.8	13.8	28.3	20.6	14.5	28.8	0.1	-1.7
CEC	6	5.3	4.5	6.1	5.2	1.6	10.5	-0.1	0.3
PH	6	7.0	6.7	7.3	7.0	0.7	3.8	0.1	-1.1
OC	6	0.8	0.5	1.0	0.8	0.5	21.3	-0.4	0.9
%Clay	6	19.7	16.0	26.0	19.0	10.0	19.7	0.8	-0.1
%Silt	6	34.3	32.0	36.0	34.0	4.0	4.4	-0.3	-0.1
%Sand	6	46.0	40.0	50.0	48.0	10.0	8.7	-0.9	-1.2
Boll_WT	6	2.7	1.7	3.8	2.6	2.1	29.4	0.3	-1.3
Sdcoty_p	6	252.0	33.0	467.0	243.5	434.0	71.1	0.0	-2.2
Lintyd_p	6	66.3	8.6	124.7	64.1	116.1	72.2	0.1	-2.1
Length	6	27.3	21.1	30.4	28.4	9.4	12.6	-1.5	2.2
Micronaire	6	4.8	3.9	6.3	4.4	2.4	20.5	0.9	-1.2

N-number of soil sample points, CV-Coefficient of Variation, Boll_WT-Boll weight, Sdcoty_p-seed cotton yield per plant, Lintyd_p- Lint yield per plant

Table 2: Ratings and Observed values for Soil Analysis Results (Soil Science Laboratory Analysis)

Ratings	Ca) **(cmol kg^{-}1)**	Ob	Mg **(cmol kg^{-}1)**	Ob.	K **(cmol kg^{-}1)**	Obs.	N (%)	Ob	P (ppm)	Ob	OC (%)	Ob
Very Low	<2		<0.3		<0.2				<5			
Low	2-5	*	0.3-1	*	0.2-0.3	*	<0.15		5-15	*	<2	*
Medium	5-10		1-3		0.3-0.6		0.15-20	*	15-30	*	2-3	
High	10-20		3-8		0.6-1.2	*	>20		30-50		>3	
Very high	>20		>8		>1.2				>50			
PH Rating	**Critical Range**				**Ob**							
Ext. acidic	<4.0											
Str. Acidic	4.1-5.2											
Acidic	5.3-6.5											
Near-neutral	6.6-7.4				*							
Alkaline	7.5-8.3											

Source: Soil Science Department, A.B.U, Zaria. Ca-Calcium, Mg-Magnesium, K-Potassium, P-Phosporous,N-Nitrogen and *Ob- Observed range in result.

Table 2: Combined Analysis of Variance for 10 Traits Influenced by 3 Potassium Levels evaluated in Samaru, 2018

Source	DF	PHT	D_50 %FL	BOL/P	SDCOT/B	SDCTYD/P	LtYD/P	BOLWT	GOT	LENGTH	MICRONAIRE
Rep(TRT)	6	515.15*	79.99*	663.01**	112.67**	40691.41	2801.99	1.96**	4.71	33.72**	0.39
TRT	2	340.86	41.57	658.04**	653.79**	892738.40**	60563.25**	5.45**	17.74	3.34	0.24
Genotype	8	651.54**	68.10*	16.83	44.75	194343.43**	13035.28**	2.26**	7.42	90.93**	2.60**
TRT*Genotype	16	67.18	17.67	17.25	14.96	33115.67	2311.91	0.47	8.49	4.07	1.92**
Error	48	229.06	28.67	15.06	23.56	38862.63	2527.33	0.45	8.71	5.66	0.81

DF-degree of freedom, D50%fl-days to 50% flowering, Bol/P-Boll per plant. SDOTYD/P-Seedcotton yield per plant, Ltyd/p-Lint yield per plant, Bolwt- Boll weight, GOT-Ginning-ou-turn

Table 3: Mean Performance for the effects of 3 Potassium Levels on Yield and Quality Traits of 3 Cotton Crosses and Parents evaluated in Samaru (2018)

Genotype	D_50_FLOWER			BOLL_P			BOLLWT			LENGTH			MICRONAIRE		
Parents	0Kgk	30Kgk	45Kgk	0Kgk	30Kgk	45Kgk	0Kgk	30Kgk	45Kgk	0Kgk	30Kgk	45Kgk	0Kgk	30Kgk	45Kgk
Clo7	95	92	93	26	34	35	2.43	3.83	3.57	25.72	26.32	28.08	4.52	3.48	5.72
Lst6	87	86	87	23	33	33	2.83	3.97	4.53	33.22	35.77	35.78	2.74	3.10	3.36
Ma13	88	92	90	23	34	34	3.20	2.90	3.50	26.75	25.02	23.11	3.77	5.24	3.53
Samcot 8	94	98	89	25	37	33	2.27	2.87	3.17	26.21	25.95	23.86	4.68	5.09	3.69
Crosses															
Clo7*Ma13	92	94	93	24	27	34	2.23	3.17	2.30	26.48	27.85	25.53	4.66	3.91	5.60
Ma13*Lst6	89	90	85	23	33	30	3.23	4.80	4.37	29.74	31.37	29.49	3.78	4.03	3.15
Sam8*Clo7	93	88	89	27	32	32	2.63	2.90	3.43	26.32	25.82	27.17	4.27	3.87	3.09
Checks															
Samcot 10	94	97	90	24	26	34	2.23	3.37	3.00	25.88	25.56	25.69	4.20	3.60	5.52
Samcot 11	90	96	95	24	34	35	2.80	3.17	2.90	28.86	29.67	28.42	3.52	4.47	4.15
Mean	91.00	93.00	90.00	24.00	32.21	33.40	2.65	3.44	3.42	27.69	28.15	27.46	4.02	4.08	4.20
CV	6.28	5.63	5.64	7.61	19.35	5.11	23.76	13.77	25.21	7.38	8.94	9.28	20.85	22.96	21.98
LSD	9.93	9.03	8.80	3.20	10.79	2.95	1.09	0.82	1.49	3.53	4.35	4.41	1.45	1.62	1.60

ASN 53rd Annual Conference Proceedings (Sub-Theme: Soil Conservation, Fertility and Water Mgt.)

Nutrients Evaluation and Management of Soils of NRCRI Nyanya FCT, Experimental Farm for Increased Turmeric Yield

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Abstract
Nutrients status of soils of National Root Crops Research Institute Nyanya sub-station Federal Capital Territory, Nigeria were evaluated to ascertain their present status and suggest management practices needed for an increased turmeric yield. Soils were sampled at 0-15 cm depth and a total of 60 composite samples were collected and analyzed in laboratory. The results revealed that the soils had a mean pH value of 6.0, exchangeable Ca (9.20 cmol kg^{-1}), exchangeable Mg (5.40 cmol kg^{-1}), exchangeable Na (1.55 cmol kg^{-1}), exchangeable K (0.58 cmol kg^{-1}), organic carbon (8.13 gkg^{-1}), total N (0.78 gkg^{-1}), available P (7.31 mg kg^{-1}). For increased turmeric yield in the soils studied, some good management practices such as boasting the organic carbon status of the soils and application of deficient nutrient elements are recommended

Keywords: Evaluation, Management, Nutrient, Soils, Turmeric

Introduction

According to Olojede and Nwokocha (2011), several words such as orphan, abandoned, new, under-utilized, neglected, lost, minor, traditional, forgotten, other, lesser, promising and under developed, have been used by some people to describe those plant species that humanity had depended upon for food and well being but which do not receive the attention or support they deserve. In Nigeria, 16 of such crops abound out of about 20 different root and tuber crops cultivated throughout the country (Asumugha and Arene, 1999). Among these crops include turmeric. Turmeric (*Curcuma longa* Linn) is a rhizomatous root crop indigenous to India (Nwokocha *et al*., 2007), it is rich in yellow food pigment called curcuminoid (6%) and essential oil (5%). The importance of this medicinal root crop cannot be over emphasis as it is used as a natural colouring agent for food, cosmetics or dye and medically for treating various kinds of diseases such as diabetes arthritis, ulcer, cancer, high cholesterol, chronic pain, depression, asthma, glaucoma, hypertension, insomnia etc. Little documented information exists on its economic importance and cultural/ agronomic practices, having suffered research attention over the years. Following the recent popularization of this crop which is presently having its research focus in the Minor Root Crops Research Programme of the National Root Crops Research Institute, through research technology development and extension delivery as well as some advocacy programs embarked upon by individual members of the programme in particular and the Institute in general, coupled with the numerous benefits farmers stand to gain from cultivating and consuming the crop. Farmers are becoming more interested in the production of this food, industrial and medicinal crop and are eager to produce it in large quantity for local consumption and for export. The major problem among others confronting these farmers in the production of turmeric is poor yield, which relies mostly on soil factor.

Declining soil fertility is a major problem militating against increase in turmeric yield in Nigeria. For Nigeria to cope with the increase in the present demand and consumption of this commodity crop soil fertility must be tackled to enhance local production. Making sustainable research on effort towards improving soils fertility status for yield increase is necessary. Therefore, soil fertility decline could be alleviated through fertilizer application, for fertilizer application to be effective the type and quality of fertilizer must depend on soil test result, otherwise soil abuse and low yield may be the result. The objectives of this work were, to determine the nutrients status of soils of National

Root Crops Research Institute Nyanya sub-station Federal Capital Territory Abuja, Nigeria and to determine management practices required for sustainable turmeric production on these soils.

Materials and Methods

Study area: The study area was National Root Crops Research Institute Nyanya sub-station Federal Capital Territory Abuja, Nigeria. It is located within latitude 7.62318° N and longitude 9.06733° E. The mean annual rainfall of the location is 1,404 mm, with mean annual temperature of 26.74°C and the vegetation is typical of Southern Guinea Savanna zone. The soils are derived from basement complex.

Sampling scheme: Soil samples were collected at 0-15 cm depth, using soil auger. A total of 60 composite samples were made, labeled and then transported to the Soil Science Laboratory of the National Root Crops Research Institute (NRCRI), Umudike, Abia State for physical and chemical analysis.

Laboratory Analysis: All the soil samples were air dried, crushed and sieved through a 2 mm mesh and re-sieved through a 0.5 mm mesh for organic carbon and total N prior to physical and chemical analysis. The samples were then analysed using standard laboratory methods as contained in the method of soil analysis by International Soil Reference and Information Center and Food and Agricultural Organization. **(**ISRIC and FAO, 2002).

Results and Discussion

Physical Properties: The physical properties of the soils of the study area are as shown in Table 1

Particle size distribution: Sand had the highest fraction with a mean value of 66.2 gkg^{-1} , followed by silt particle size fraction with a mean value of 225 gkg^{-1} and clay had the least fraction, with a mean value of 113 gkg^{-1}.The particle size distribution is an indication that the soils originated from coarse parent materials as reported by Onyekwere *et al* (2010).

Textural Classification: The texture of the soils is sandy loam. Generally, the textual classification of these soils agrees with optimum criterion of light medium loam sandy soil (Onyekwere *et al*.,2009) required for unhindered anchorage and bulking of roots and tubers including turmeric and for easy harvest. This is an indication that it is good for turmeric production.

Primary nutrients*:* N, P and K are the primary nutrients most commonly demanded by crops in plant nutrition. This explains why most compound fertilizers and fertilizer requirements for the crop (turmeric) is based on N, P and K and their results are shown in Table 1

Total N: The results obtained showed that the total N of the soils studied was low with a mean value of 0.78 gkg^{1}. The result of total N is a reflection of the organic carbon content of the soils (Onyekwere *et. al*., 2009). Positive response of turmeric to applied nitrogen fertilizer is thus expected in these soils.

Available P: Available phosphorous value of the soils was low with a mean value of 7.13 $mgkg^{-1}$. This suggested that the soils will show substantial response to applied phosphorus fertilizer for turmeric production.

Potassium: The exchangeable potassium content of the soils studied was high with a mean value of 0.58 cmol kg^{-1}. The soils had mean value that is above 0.20 cmol kg^{-1} value regarded to be the critical exchangeable K level in the soils (Onyekwere, *et al,* 2018).

Some selected chemical Properties: The results of some chemical properties of the soils of the study area are shown in Table 1.

Soil Reaction: The soil reaction as expressed by pH (H_20) was moderately acidic with a mean value of 6.0. Agronomically, the mean pH value of the soils is good for turmeric cultivation, as it can make room for the availability of both macro and micro nutrients as well enhancing the activities of microorganisms in the soils.

Organic Carbon: The Organic carbon content of the soils is low with a mean value of 8.13gkg^{-1} Maintenance of a satisfactory organic matter status in these soils is highly essential, Onyekwere and Ezenwa (2009) repotted enhanced mineralization of most of the nitrogen and half of the phosphorous in the soils, if the turmeric fields were unfertilized

Calcium: The exchangeable calcium of the soils studied was high with mean value of 9.20 cmol kg^{-1}. Soils of the study area had mean value above 4 cmol kg^{-1} regarded as lower limit for fertile soils (Onyekwere *et.al.,* 2001)

Magnesium: The exchangeable magnesium content of the soils studied was high 5.40 cmol kg^{-1}., the soils are well endowed with exchangeable magnesium.

Sodium: The exchangeable sodium content of the soils was high with a mean value of 1.59 $cmolkg^{-1}$. The soils had exchangeable Na above 0.2 $cmolkg^{-1}$ regarded as the critical value needed in soils (0nyekwere, 2018).

Conclusion

The findings in this study gave the indication that the textural classification and the soil reaction of the soils are ideal for turmeric production. They can give room for the availability and uptake of both micro and macro nutrients. That the soils are further characterized by low organic carbon, high exchangeable Ca, Mg and Na, low primary nutrients apart from potassium. Based on these finding, incorporation of crop residue and other organic inputs and application of 60 kg N/ha, 26 Kg P_2O_5 /ha and 5 Kg K_2O /ha fertilizes are suggested for an increased turmeric yield on the soils studied

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Table 1: Mean values of the Physical and chemical properties of the soils studied

Parameter	Mean value
Sand (gkg^{-1})	662
Silt (gkg^{-1})	225
Clay (gkg^{-1})	113
Textural class	Sandy Loam
pH	6.0
Organic Carbon (gkg^{-1})	8.13
Total Nitrogen (gkg^{-1})	0.78
Exchangeable Ca (cmol kg^{-1}.)	9.20
Exchangeable Mg (cmol kg^{-1}.)	5.40
Exchangeable K (cmol kg^{-1}.)	0.58
Exchangeable Na (cmol kg^{-1}.)	1.55
Exchangeable Acidity (cmol kg^{-1}.)	0.14
Avaiable l P ($mgkg^{-1}$)	7.31

ASN 53rd Annual Conference Proceedings (Sub-Theme: Soil Conservation, Fertility and Water Mgt.)

Pond Wastewater Treatment and the Possibility for Re-Use

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Abstract
This study was carried out to address a persistent problem of water shortage, pollution of water and indiscriminate discharge from ponds. Water sample was collected from commercial fish farm to determine the various physicochemical parameters using standard limnological method. The wastewater was sampled and analyzed for dissolved oxygen (DO), pH, conductivity, total alkalinity, total hardness, calcium, magnesium, chloride, nitrate, phosphate, total dissolved solids (TDS), chemical oxygen demand (COD), biochemical oxygen demand (BOD), total bacteria count (TBC) and for heavy metals like manganese (Mn), copper (Cu), iron (Fe) and zinc (Zn). FAO /WHO and UNEP recommended limits for tolerable heavy metal intake for man and physicochemical parameter standard for water was used. The physicochemical parameter test conducted shows D.O =8.26mg/L, conductivity =510mg/L, total alkalinity =70mg/L, pH =7.22, TDS =326mg/L, COD =14.50mg/L, total bacteria count =47.7cfμ/L while iron (Fe) showed the highest level of heavy metal contamination in the wastewater with 6.56mg/L. The result obtained indicated pollution and unpleasant odor. While some parameters although high were within the acceptable limit, others were above the recommended standard. It is therefore necessary to treat wastewater prior to discharge or re-use to reduce pollution and the pressure of water scarcity especially during dry season.

Introduction

Pollution of water is a global challenge on the increase both in developed and developing countries, this in turn has greatly undermine the economic growth as well as the physical and environmental health of billions of people (Javier *et al.,* 2017). Although global attention has focused primarily on water quantity, water use, efficiency and allocation issues, poor wastewater management has created serious water quality problems in many parts of the world, worsening the water crisis (FAO, 2016). The change in water quality or composition directly or indirectly as a result of both natural and human activities such that it becomes unsuitable for domestic, agricultural, fisheries and other purposes for which it would otherwise be quite suitable in its uncontaminated state is regarded to as water pollution (Woodford *et al.,*2015). These pollutants are usually pathogens, silt and suspended solids particles such as soils, sewage materials, disposed foods, cosmetics, automobile emissions, constructed debris and eroded banks of rivers and other water ways (Akpan and Ajayi, 2016). In African countries, Nigeria in particular, water related diseases has increasingly been interfering with basic human development (WHO, 2015). Numerous economic and scientific facts revealed that shortage of water or its pollution can cause severe decrease in productivity and death of living species (UNICEF, 2008). One of the major issues of national and international interest is how these water pollution problems could be fully accessed and reduced. Thus, proper knowledge and planning are essential (Galadima *et al*., 2011). The most basic and essential substance for the sustainability of life on earth is water. Access to clean water and its sources are insufficient and these can be attributed to population explosion, climate change, industrial and agricultural activities, (Campelo *et al.,* 2017). As the demand for clean, safe and sustainable water increases, and drinking water shortage, a great emphasis or demand will be placed on wastewater recycling (Wang *et*

al., 2018). The World Health Organization (WHO, 2016) estimates that 6.3% of all deaths are caused by limited access to safe drinking water, hygiene practices, improved sanitation facilities and water management practices. It was reported that about 780 million people predominantly in Africa and Asia do not have access to clean and safe drinking water (UNICEF and WHO,2015). Increase in agriculture and agricultural activities play an important role in the economic and industrial development of every country which in turns, contribute largely to improving domestic products and improved standard of living. However, these growing agricultural activities especially fish farming and aquaculture cause an increase in discharge of polluted water into surrounding environment. Despite an increase awareness on the negative impact of such discharge of polluted water, indiscriminate discharge of waste water still persist resulting to pollution and unpleasant odor emanating from the discharge surroundings. It has been estimated that 70 % of industrial and agricultural water in all developing countries were discharged into waterways without treatment. (Leao *et al.,*2017). Waste water discharge influences the quality of surface water, which in turn affects the health of humans and the ecosystem. Heavy metals like iron, copper, lead, manganese, zinc, mercury pose a serious threat to public and human health. Their occurrence has a harmful consequence on the physiology and biological systems of humans if the tolerance levels are exceeded (WHO, 2017). Due to higher consumption of water and drinking water shortage, a high emphasis will be placed on waste water recycling. In particular, it will be necessary to treat water and make it fit for reuse and a particular purpose (Emir *et al*.,2018). The most important methods used in wastewater purification include screening, filtration, micro and ultrafiltration, crystallization, sedimentation, gravitysepration, floatation, precipitation, oxidation, adsorption, neutralization. (Ali,2012). The above methods can be combined depending on the type of polluted water and the purpose of it use. The convectional waste water treatment methods involves physical, chemical and biological processes which results can be limited because of high cost or due to poor treatment efficiency (Qu *et al.,*2012). Therefore, in view of the various problems associated with the conventional waste water treatment methods, there is need to develop an efficient, practical and sustainable techniques to remove toxic organic and inorganic pollutants from water and make it reusable.

Materials and Methods

Wastewater sample was collected form a commercial earthen pond fish farm, which was then analyzed. The American public health association method (APHA) was used to determine pH, conductivity, total dissolved solids, total hardness, total alkalinity, dissolved oxygen, chemical oxygen demand, nitrate and phosphate while biological oxygen demand was by bottle incubation (5days), total bacteria count was by using elevated temperature fermentation method and the heavy metals like iron, manganese, copper and zinc were determine using atomic absorption spectrophotometry.

Result and Discussion

The result presented in the table shows that the conductivity of the wastewater, the total alkalinity, magnesium, dissolved oxygen and phosphate was high. The bacteria count was above the permissible limit set by WHO/EPA, while the heavy metals present were also on the high side. Although majority of these parameters falls within the permissible limit, the resulting effluent discharge is toxic to the environment when in large quantities which produces an offensive odor and can cause algae bloom in the environment.

Conclusion

In summary, the study focused on the possibility of wastewater reuse or treatment before discharge from fishpond. From the obtained result, indiscriminate discharge into the surrounding and the environment at large must be discouraged and effectivity curbed. It is recommended that safe, effective and environmentally friendly methods should be develop to help fish farmers reuse their wastewater for culturing and other agricultural activities.

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TEST	RESULT	STANDARD LIMIT (WHO/EPA)
pH	7.22	5.5-8.5
CONDUCTIVITY (µS/cm)	510	1000
TOTAL HARDNESS (mg/L)	74	500
TOTAL ALKALINITY (mg $CaCO_3$/L)	70	20-200
CALCIUM (mg/L)	12.61	75
MAGNESIUM (mg/L)	42.50	50
CHLORIDE (mg/L)	45.34	250
NITRATE(mg/L)	2.88	50.0
PHOSPHATE (mg/L)	0.47	0.5
TDS (mg/L)	326	600
C.O.D (mg/L)	14.50	40.0
DISSOLVED OXYGEN	8.26	5-6
B.O.D (mg/L)	5.30	6-9
HEAVY METALS		
MANGANESE (mg/L)	0.18	0.50
IRON (mg/L)	6.56	0.50
COPPER (mg/L)	0.28	1.00
ZINC (mg/L)	0.42	2.00
TOTAL BACTERIA COUNT (cfu/L)	47.7	2.0

ASN 53rd Annual Conference Proceedings (Sub-Theme: Soil Conservation, Fertility and Water Mgt.)

Proximate Compositions of *Clarias gariepinus* from Selected Dams in Niger State

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ABSTRACT
This study was conducted to evaluate the proximate compositions of *Clarias gariepinus* from selected dams in Niger state, Nigeria. Niger state comprised of three geo-political zones namely Zone A, B and C. the selected dams were Agaie Lapai dam in zone A, Shiroro dam in zone B and kainji dam in zone C respectively. *Clarias gariepinus* were collected from the selected dams from each zones. Crude protein, moisture, ash, lipids and nitrogen free extract contents were analyzed using the AOAC methods. The species shows significant differences ($p<0.05$) in the results of the proximate analysis. However, Moisture content was recorded significantly high $p<0.05$) in all the species of *Clarias gariepinus* from Agaie- lapai dam in zone A(75.18±0.01) and low in kainji dam in Zone C(72.34±0.01). The crude protein content was significantly high ($p<0.05$) in zone C *Clarias gariepinus* (10.68±0.01) and low in in Agaie-lapai dam in zone A, lipids contents recorded highest in *Clarias gariepinus* in zone A (5.04±0.01) and significantly low ($p<0.05$) in zone C (3.86±0.0). The ash content in *Clarias gariepinus* was high in Zone C (2.72±0.01) and low in zone A (1.44±0.01) while the nitrogen free extract was significantly highest in shiroro dam in zone B (11.22 ±0.01) and low in zone A (9.16±0.01) respectively. The research revealed that, Zone C *Clarias garipinus* is high in crude protein while Zone A has high lipid content.

Keywords: *Clarias gariepinus,* Moisture, Crude Protein, Ash, Lipids

Introduction

Fish is an important animal protein and has been widely accepted in the world, as a good source of protein and other elements for the maintenance of healthy body compared to meat (Adeniyi *et al*., 2012).With the world's population expected to reach 8.2 billion by 2030, and with 842 million people estimated undernourished during 2011–2013, food supply will present a growing challenge in the next two decades. With increase in income along side with demographic changes related to family size, population growth, urbanization and consumer trends such as concerns for eating healthy foods and sustainable production, there will be a great shift in demand and major changes in the composition of demand. This situation will in turn have an impact on food supply, which will need to increase and become more efficient if it is to grow within the constraints presented by the availability of natural resources and existing technology (FAO, 2014). Presently, fish consumption has been increasing worldwide, mainly due to the availability, accessibility and price in relation to meat consumption, such as, poultry, pork, and beef. Therefore, some concerns begin to emerge, primarily regarding the quality of fish available in the market. Chemical residues could be present in any product of animal origin causing economic losses and putting into a risk of human and animal health. According to Bostock *et al*. (2010), aquaculture contributes nearly half of all food of aquatic origin for the purpose of human consumption, as a vital part of the global food industries. The chemical components of fish comprises of mainly water, proteins, and lipids. These components are the most important in terms of nutritional value (Ros *et al.* 2010).Nutritional value of the fish depends on many factors that can further be divided into intrinsic factor, dietary factors and Environmental factors (Grigorakis, 2007).The fisheries sector of Nigeria consists of capture and aquaculture fisheries. Capture fisheries is further sub-divided into industrial and artisanal which flourish well inside and outside to the open deep waters of 200nm EEZ across the 9 coastal states of the country's coastline (Ipinmoroti, 2012; Oladimeji *et al*., 2013; Okeowo *et al*., 2015).

Materials and Methods

African catfish (*Clarias gariepinus)* of average body weight of 200g at 25cm in length were collected from Agaie-lapai dam located in Zone A on lat. $9^0$23"N, long. $6^0$58"E, Shiroro dam located in Zone B at lat. $9^0$53"N,long. $6^0$50"E, and Kainji dam located in zone C on lat.$10^0$21"N, long.$4^0$32"E and were analyzed according to Association of official Analytical chemist (A.O.A.C, 2002) was used to determine moisture, lipids, crude protein, ash and nitrogen free extract respectively.

Result

Proximate Compositions of *Clarias gariepinus* From Some Selected Dams In Niger State

Table 1: The Proximate composition of whole *Clarias gariepinus* from Agaie lapai dam in zone A has a significantly high $p<0.05$) moisture content of 75.18% while zone C exhibited a significantly low ($p<0.05$) moisture value (72.34%). The crude protein was significantly high ($p<0.05$) for Zone C (10.68%) however, Zone A (9.18%) and B (9.25%) are not significantly different ($p>0.05$) from each other. Zone A also has a significantly high ($p<0.05$) lipids content (5.04%) while zone C had a significantly low ($p<0.05$) lipid value (3.86%). The ash was significantly high $p<0.05$) for Zone C (2.72%) and significantly low ($p<0.05$) for Zone A (1.44%). The nitrogen free extract was significantly high ($p<0.05$) for Zone B's *C. gariepinus* (11.22%) while those of Zone A gave a significantly low ($p<0.05$) NFE value (9.16%).

Discussion

The proximate compositions of *Clarias gariepinus* (protein, lipid, moisture, ash and nitrogen free extract) were the major contents which were considered in evaluating the nutritional value of the specie studied. The proximate compositions of *Clarias gariepinus* vary considerably. Stansby (1985); Azim *et.al* (2012) reported that variation in proximate composition of fresh fish may vary with species variation, season, age and feeding habit of the fish. The result of the present study shows that there was fluctuation in moisture and lipid value of whole *Clarias gariepinus* from different zones in Niger state. This variation in moisture and lipid content of the samples showed that with a gradual decline in moisture content, fat content gradually increased, this result agrees with the previous works reported on freshwater fisheries by Sadiku and Oladimeji (1991); Bake and Sadiku (2012); Bake *et al.,* (2014). Huss 1995;Saoud, *et al*., (2007), also reported that fat content has shown inverse proportionality to water content in some semi fatty fish species muscle, this may be attributed to the seasonal differences, availability of food and changes in the reproductive cycle having considerable effect on the tissue biochemistry of the fish particularly changes in the lipid and water content of their body system. The nutritional elements showed variable values in all the fishes analyzed; with crude protein recording the highest value and lipid recording the lowest. This makes the fishes important living resources of dietary protein as other sea and freshwater fish (Zuraini *et al*., 2006). High lipid fishes had less water and more protein than low-lipid fishes. This is in-line with the report of Steffens (2006), that protein forms the largest quantity of dry matter in fish. The high moisture content would increase the deterioration level of fish when kept for a long time. This is because micro-organisms would be highly active with high moisture content (Love, 1980). Similar observation has been reported by Aboluade and Abdullahi (2005), Otitologbon*et al.* (1996).

Conclusion

This study shows that fresh fish from some selected dams from Niger State Nigeria are of good and wholesome biochemical quality for immediate consumption. However, they can be utilized maximally by food processors in fish canning and other value-added fish products such as fish burger, fish cake and fish crackers and also for use in controlling diet while the wastes recovered can be used for fish meal or silage production for animal feeds. Hence, they are suitable as potential industrial material for possible utilization for different products.

Recommendation

It is therefore recommended that, fresh fishes under good physiological condition are good for consumption as food in relation to health status of individuals and the community. The fishes have high protein that can supplement the protein needs of the people in the communities in and around the dam.

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Zones	Proximate compositions (%)				
	Moisture content	Crude protein	Crude Lipids	Ash	Nitrogen free extract
A	75.18^{a} ±0.01	9.18^{b}±0.01	5.04^{a}±0.01	1.44^{c}±0.01	9.16^{c}±0.01
B	73.31^{b}±0.01	9.25^{b}±0.01	4.27^{b}±0.01	1.95^{b}±0.01	11.22^{a}±0.01
C	72.34^{c}±0.01	10.68^{a}±0.01	3.86^{c}±0.01	2.72^{a}±0.01	10.40^{b}±0.01

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Spatio-Temporal Studies of Sea Surface Temperature and its Respond on Precipitation in the Gulf of Guinea

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Abstract
Present study undersees spatio – temporal pattern of sea surface temperature and its respond on precipitation in the Gulf of Guinea North latitude (GOGN) $(0-10)^{o}N$. Monthly mean reanalysis sea surface temperature data obtained from revised version 5 Extended Reconstructed Sea Surface Temperature (ERSSTv5) with $2^{o} \times 2^{o}$ spatial resolution and monthly mean $2.5^{o} \times 2.5^{o}$ gridded reanalysis precipitation data from (NCEP– NCAR) spanning from 1979 to 2018 were used for the present study. It was observed that the spatial SST distribution in the Gulf of Guinea attain its highest in July – August – September – October with highest temperature recorded in September with slight increase in November. The result also show that least SST was observed in December – January – February – March with lowest in February. Result show that SST and Precipitation are reciprocals of each other with strong spatio – temporal correlation in the latitude above 4^{o}N in May, June, July, August, December, January, February respectively.

Introduction
Establishing a relationship between anomalies in sea surface temperature (SST), perturbations in the atmospheric circulation and response in precipitation forms the physical basis of seasonal to interannual prediction of climate change. Several studies have reported that West Africa comprises of ecological zones with drought tendency, most notably in the Sahel Zone (SHZ) and some extent, over the Guinea Coast Region (GCR) (see e.g. Nicholson, 2001; Le Barbe et al., 2002; Paeth and Hense, 2006). Cases of famine have been reported in West Africa since 20th century as a consequence of drought, this include drought periods of 1913–1914, 1931–1932, 1942–1943, 1972–1973 and 1983–1984 (Jao and Apeldoom, 1978; Sagua et al., 1987; Mijindadi and Adegbehin, 1991). This have brought untold hardship, starvation and agony to the inhabitant as a result of ecological damage posed to plants and animals as a result of drought. It is against this background that many studies on the climate of West Africa are focused on identifying the relevant forcing factors in order to establish forecast systems at seasonal to inter-annual time scales. This will enable farmers to plan with greater confidence, and mitigate the negative consequences and exploit its beneficial opportunities (Adedokun, 1978; Mo and Thiaw, 2002). Sea surface temperature, one the significant aftercome Ocean – Atmosphere interactions has been shown to be related and varies with precipitation (SSTs; Pegion and Kirtman 2008; Wu et al. 2008; Chen et al. 2012). Sea surface temperatures defines the predictability of climate in sub-Saharan Africa. The warm phase of ENSO, the dominant pattern of variability at global scale, is associated with drought at the margins of the monsoon systems of the northern and southern hemispheres during the respective rainy seasons. These fall in the middle of the calendar year during ENSO growth in northern Africa, in the Sahelian belt stretching from the Atlantic coast of Senegal and Mauritania to the Red Sea coast of Sudan and Eritrea, and at the beginning of the calendar year after peak ENSO in southern Africa. Here we explore the observed monthly mean relationships between sea surface temperatures and precipitation and investigate the extent to which regional increases in precipitation may have been moderated by increases in sea surface temperatures.

Materials and Methods

Monthly mean reanalysis sea surface temperature data obtained from revised version 5 Extended Reconstructed Sea Surface Temperature (ERSSTv5) (Huang et al, 2017) and monthly mean gridded reanalysis precipitation data from (NCEP– NCAR) spanning from 1979 to 2018 were used for the present study. ERSSTv5 product which is of $2^o \times 2^o$ spatial resolution and NCEP precipitation product $2.5^o \times 2.5^o$ spatial resolution was downloaded from
http://www.esrl.noaa.gov/psd/data/gridded/data.noaa.ersst.v5.html and
https://www.esrl.noaa.gov/psd/data/gridded/data.cmap.html respectively, temperature is in degree centigrade (o_C) and precipitation in kilogram per meter square (Kg/m^o). The study location (GOGN) i.e. $(0 - 10)^o$N was extracted from the dataset, the subset was then used to estimate and determine the following indexes: Seasonal mean, Seasonal anomaly, monthly anomaly etc. these indexes were represented and presented in the result below, all the analysis were performed with python program.

Results and Discussion

A key ingredient in the correlations is the magnitude of the variability, as given by the mean deviations in (figure 1a, 1b, 2a, 2b) below. In many respects SST and Precipitation are reciprocals of each other, with high variability in the tropics i.e. from 0 – 4 latitude and low at high latitudes. The correlations were more pronounced in May, June, July, August, December, January, February. It was observed that the spatial SST distribution in the Gulf of Guinea attain its highest in July – August – September – October with highest temperature recorded September with slight increase in November. The result also show that least SST was observed in December – January – February – March with lowest in February. The result also shows some spatio – temporal behavior of sea surface temperature with variations in both longitude and latitude with highest temperature values recorded at 5^o latitude and 181^oE longitude. The result obtained also show a decline SST in December and reaches its minimum in January – February which translate to a cold weather and a reduced rainfall that appears to coincide with the period of Harmattan season over West Africa. Slight increase in SST accompanied the minimum SST in April and keep increasing until second week of November. It is worthy to note that SSTs at these periods are above the normal mean SST, this event is associated with increased convection and precipitation, and the relationship is driven by the SSTs forcing the atmosphere, these periods of the year coincides with rainy season over West Africa. Result show that SST and Precipitation are reciprocals of each other with strong spatial and temporal correlation in the latitude above 4^oN and in the period May, June, July, August, December, January, February respectively. Literature have shown that higher SSTs will encourage precipitation both through surface evaporation increasing humidity and vertical atmospheric instability increasing convection, tending to result in positive SST-precipitation correlations with SST leading precipitation (e.g., Kirtman & Vecchi, 2011). The resultant SST and precipitation correlations have attributed balance between these Ocean and Atmospheric Forcing, as has been demonstrated both in observations and in coupled general circulation models (Arakawa & Kitoh, 2004; Lau & Sui, 1997; Rajendran et al., 2012; Wu & Kirtman, 2005; Wu et al., 2006). The results of the present study also agree with literature (Weisberg and Tang (1983), (Folland et al., 1991; Berte and Ward, 1998; Philippon and Fontaine, 2000; Omotosho et al., 2000; Gbuyiro et al., 2002; Wilson, 2002; Odekunle and Gbuyiro, 2003; Odekunle et al., 2005; British Met Office, 2006).)

Conclusions

The study has examined the spatio-temporal SST patterns int the GOGN and discussed their responds on precipitation. It was discovered SST has a great influence and a strong correlation on the precipitation. Mean SST agrees with precipitation in all respect with strong agreement in latitude above 4^oN. SST in the study area also show a spatial and temporal dependency as it varies with location and time. This study also agrees with literature that SST and precipitation relationships are a result of air-sea interactions, with the two main contributors to SST cooling being precipitating cloud and convection.

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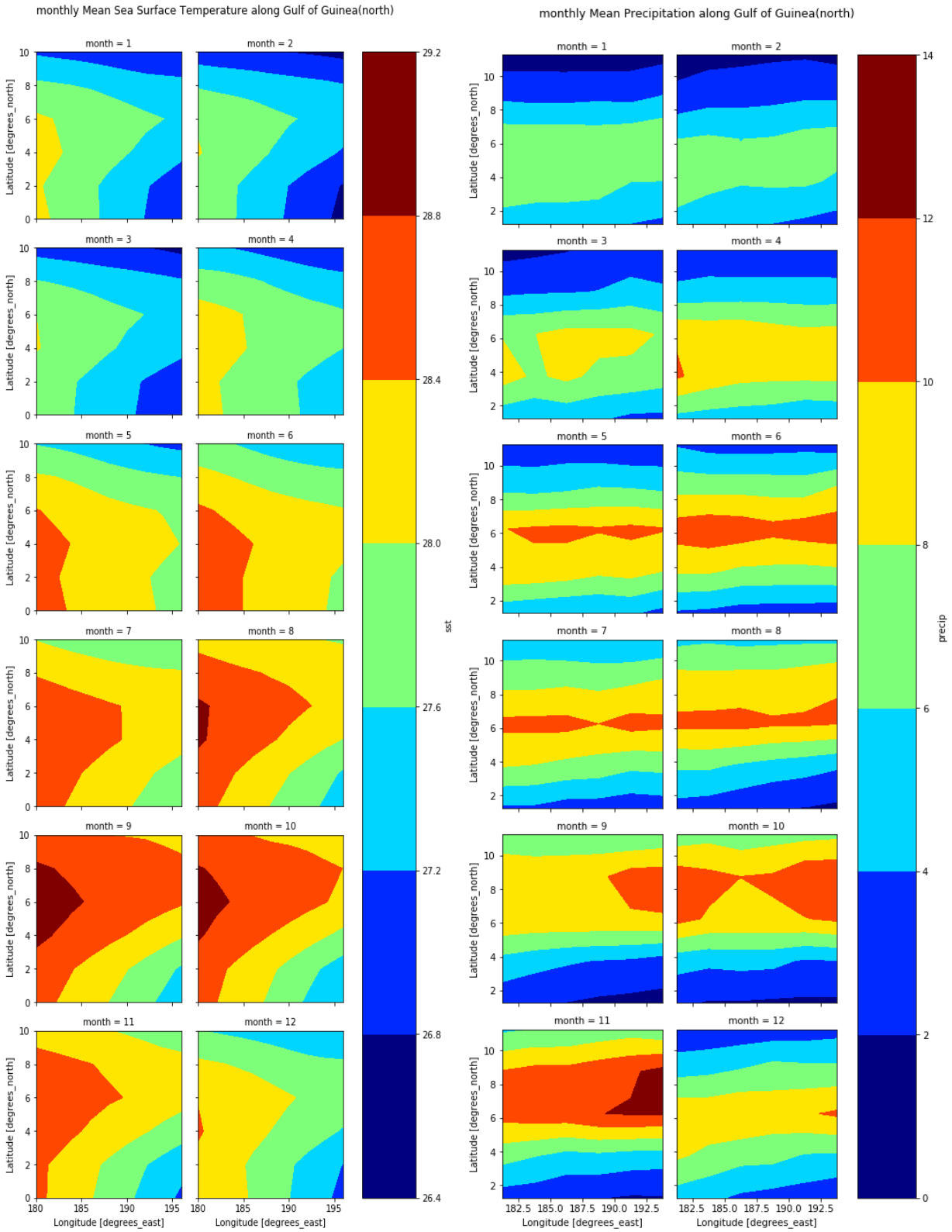

Figure 1.1a Monthly mean SST and Precipitation in the Gulf of Guinea (North)

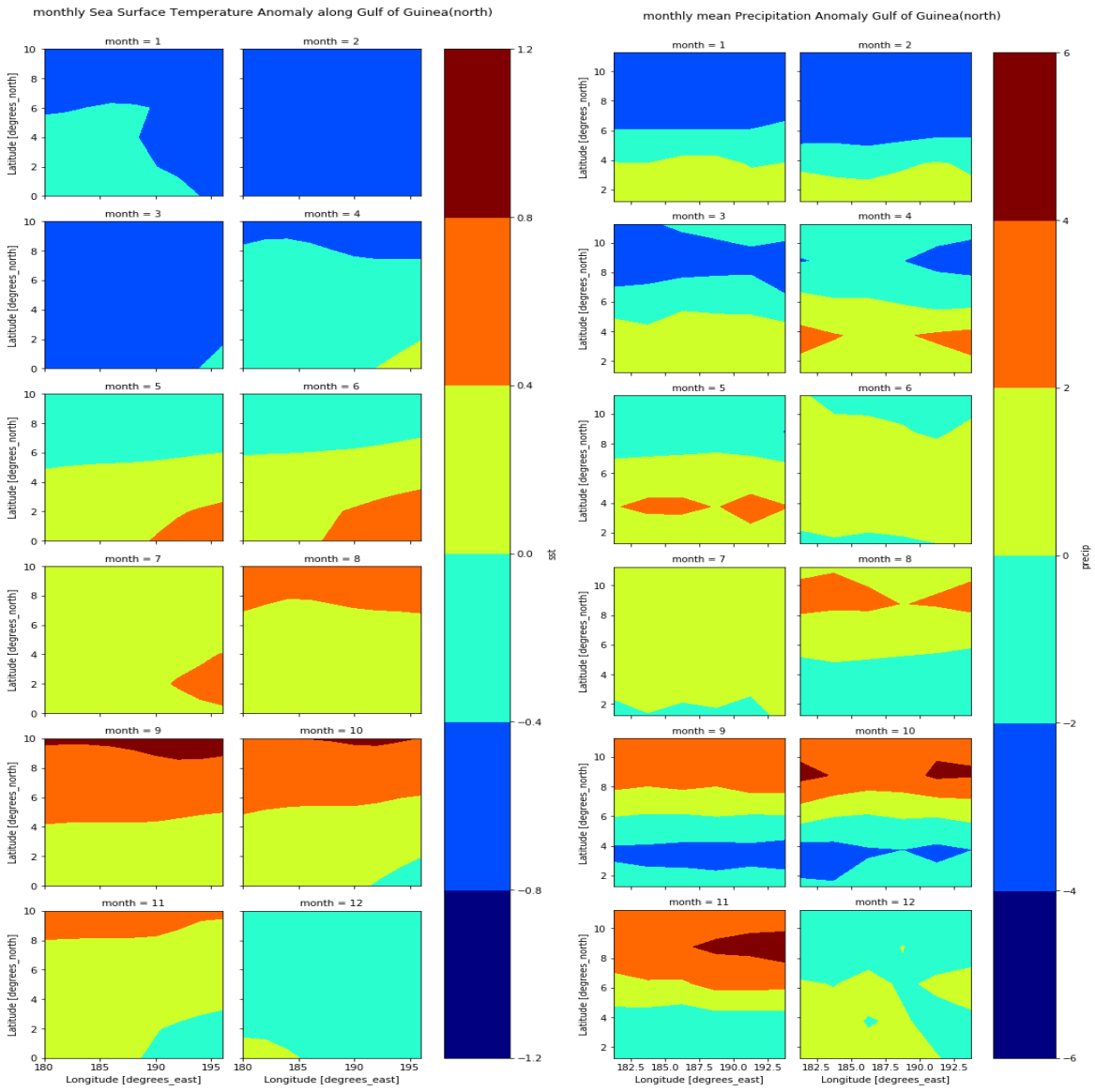

Figure 1.1b Monthly mean SST and Precipitation Anomaly in the Gulf of Guinea (North)

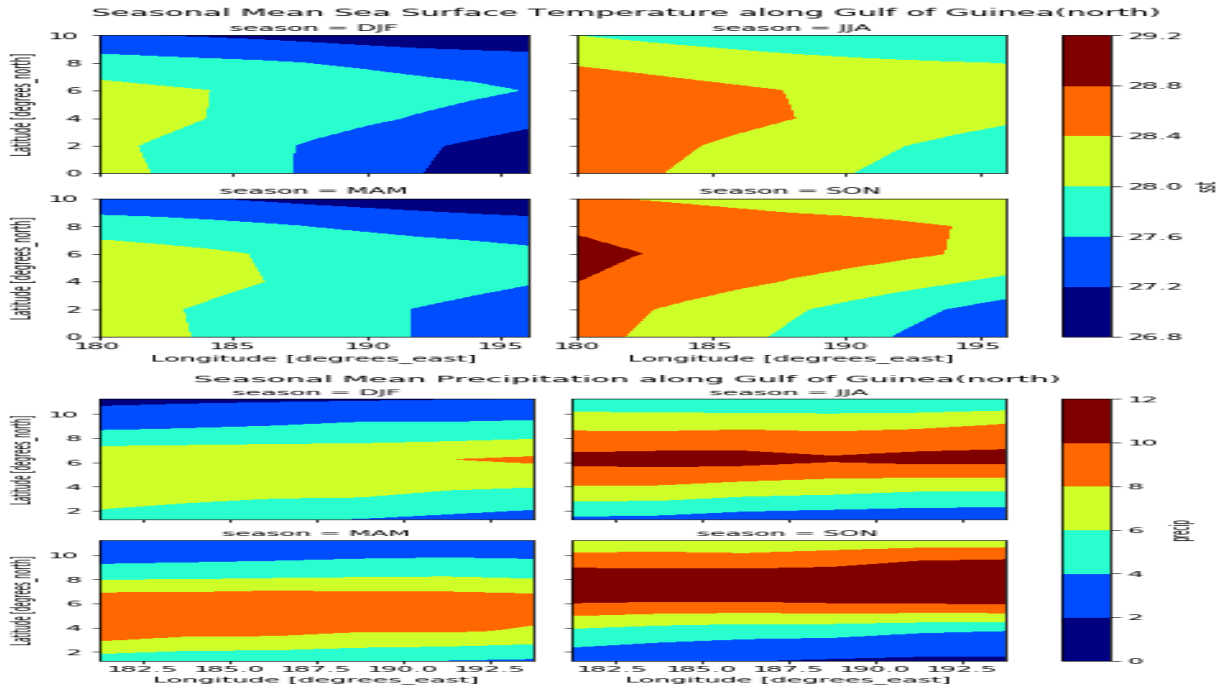

Figure 1.2a Seasonal mean SST and Precipitation in the Gulf of Guinea (North)

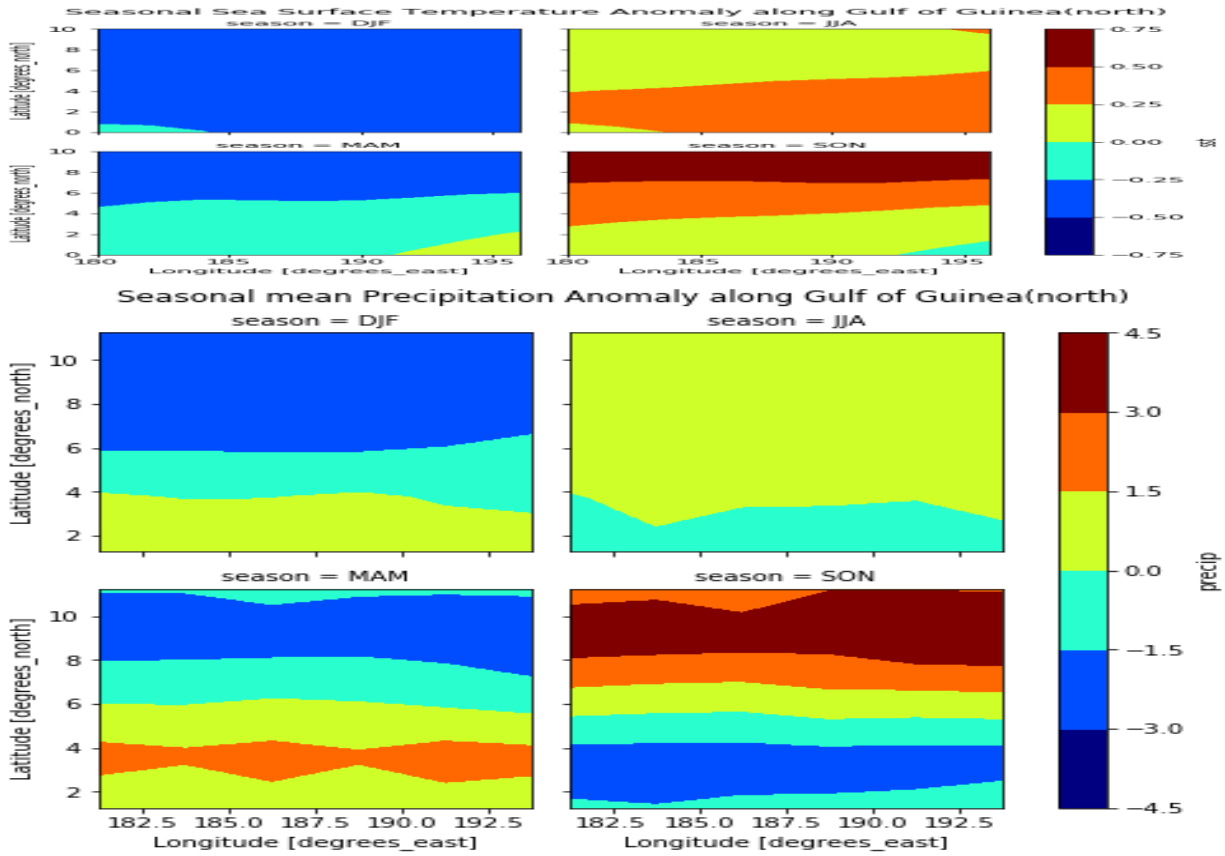

Figure 1.2b Seasonal mean SST and Precipitation Anomaly in the Gulf of Guinea (North)