

Impact of the use of Inorganic Fertilizers to the Soils of the Ebonyi State Agro-Ecology, South-Eastern Nigeria.

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Abstract
There is the fear that long term application of inorganic fertilizers to the soils of the Ebonyi state Agro- ecology could have contributed to the soils productivity constraints. A study was therefore conducted in the major crop production communities, representing the major soils of the state, to assess the impact of long term use of inorganic fertilizers on the soils. Soil samples were collected from fifteen different farm locations that have the records of continuous application of inorganic fertilizers and analyzed for their physical characteristics, chemical properties, and microbial population. The Results of the analysis indicated that the soils were very strongly Acidic to strongly acidic (4.0-5.6), whereas exchangeable acidity (EA) was very high across the entire locations. Organic carbon (OC) ranged from low to high (0.51-1.84); Cation Exchange Capacity (CEC) was very low across the locations (1.65-4.5), whereas base saturation ranged from very low to low (42.06-50.10). Total Nitrogen and exchangeable phosphorus ranged from moderate to medium (0.09-0.19 and 5, 70-24.8); potassium, calcium, magnesium and sodium ranged from very low to low (0.05-0.32; 0.86-5.10; 0.30-2.0 and 0.09-0.25) respectively across the locations. The soil microbial populations were however stable and consistent with normal microbial population for natural agricultural soils. The application of lime and complementary use of organic manure and mineral fertilizers were recommended as a sound fertility management strategy for these soils.
Key Words: Inorganic Fertilizers; Soil Acidity; Nutrient elements; Microbial population; Soil fertility.

Introduction

Most of the inhabitants of Ebonyi state are farmers by occupation. Over most of the area, families depend on home-grown food for their daily diet and income. It has been observed that almost all the land which can be cropped are already in use, and large scale crop production in the area depends on use of inorganic fertilizers. However yield of crops has remained low in recent times and even crop yield declines are commonly observed.

Scientific investigations (works) have revealed that low fertility of the soils is the primary constraint to increased crop yields (Ogbodo 2009ab, 2010). Researchers have proffered reasons for such situations elsewhere which pointed primarily to, and solutions which bordered mostly on inorganic fertilizer use. Bune-mann and McNeill 2004 showed that fertilizers can bring about undesirable changes to the soil chemical environment, and harm to the organisms that come in contact with the chemical, or food sources of organisms.

With current levels of inorganic fertilizer use in the area, at about 400 kg ha^{-1}, the potential for fertilizers to have negative impacts on productivity and environmental quality is great, leading to productivity declines and environmental problems. It is therefore essential that agencies promoting increased fertilizer use be aware of the potential for negative impacts since the use has become widespread, so that appropriate agricultural management strategies, monitoring systems, and policies can be put in place to limit the negative impacts.

This study assessed the impact of long term inorganic fertilizer application on the soil. Specifically the study evaluated the impacts of inorganic fertilizers on the soil and suggested strategies that have the potential to minimize the negative impacts and maximize positive impacts to address the constraints of farmers to improve agricultural out-put.

The results would provide a base line data that will be beneficial to appropriate government agencies and policy makers in taking decisions on the safe use of fertilizers in the future.

Materials and methods

Location

The study was conducted in fifteen farm locations, purposively chosen based on the records of the state Agricultural Development Program, and representing the major soils in the state. The specific global positioning of the farms is shown in table 1. Each of the farms had up to twenty years records of exclusive inorganic fertilizer application. The state has derived savanna ecology on the northern one half, and low rain forest on the other southern part. The soil is described as Ultisol and the underlying geology made up of shale parent material. The rainfall pattern is bimodal with peaks in July and September, while the annual rainfall averages around

1500mm in the northern half and 2000 mm in the southern part. The minimum and maximum temperatures range from 29 – 33^0 C (FDALR, 1985).

Field study

The study was conducted in 2012, and covered the major farming communities in Ebonyi state, and which soils are representative of the major soils of Ebonyi state. The work involved reconnaissance survey of the entire areas (locations), and the establishment of sampling zones using the heterogeity of the landscapes. Soil-samples for physical and chemical determinations were randomly collected from 20 sites in each area, at 0-40 cm depth, bulked together, and a sub-sample taken for analysis as representative of the location. Twenty soil samples for microbial determination were also collected from each of the various locations using sterile trowels and transferred to sterile sampling bottles and labeled. About 200 grams of soil sample was collected for each sampling zone, and transported in an ice pack to the laboratory and analyzed immediately. The samples collected for microbial determinations were analyzed separately and the mean of the twenty samples determined as representative of each location respectively.

Laboratory methods

The samples for physical properties were processed and analysed for texture following the procedures of Soil Survey Laboratory Staff (1992), whereas the chemical properties were determined by the method of IITA 1979. For the bacteria and fungi load determination, standard plate count was carried out on the soil samples using the method described by Harold (1998). Plate count agar was used for total bacterial count while potato dextrose agar was used for fungi count. Duplicate plating was done for all the dilutions. Plate count agar plates were incubated at 35^{o}C for 48 hours while potato dextrose agar plates were incubated at 25^{o}C for 96 hours.

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Data analysis

The results were statistically analyzed, using simple statistics, and compared with standards. The designation of the status soils chemical properties were established using the methods of federal Department of Agricultural Land Resources, (1990).

Results and discussion

Table (2) shows particle size distribution, the sand content is generally higher than silt and clay contents. Generally, the textural classes ranged from loam to clay. At Akaeze, the epipedon and endopedonare predominated by clay underlain by clay loam soils. Apart from this outlier, one can describe the soils of the fifteen locations as fine loamy soils (Table 2). The predominance of sand and clay separates indicates the water holding capacity of the soils moderate. The textural classes indicate that the soils are likely not to be waterlogged, and drainage will not pose a problem.

The chemical characteristics (Table 3) show the soils to be very strongly Acidic to strongly acidic (4.0-5.6) almost across the entire locations. Organic carbon ranged from low to high (0.51-1.84) across the locations. Exchangeable acidity was very high over the entire locations; CEC was very low (1.62-4.5), whereas base saturation ranged from very low to low (42.06-50.95) across the locations. Total Nitrogen and exchangeable phosphorus ranged from moderate to medium (0.09-0.19; 5.70-24.80) respectively; potassium, calcium, magnesium and sodium ranged from very low to low (0.05-0.32; 0.86-5.10; 0.30-2.0 and 0.09-0.25) respectively across the locations.

The fertility inference is that the soils are naturally not endowed with soil nutrient elements. They suffer multiple nutrient deficiencies, despite the fact that the soils have records of receiving inorganic nutrients (chemical) annually as an essential component of the farming system, and which the aim is to maintain good yield in the absence of sufficient organic, natural manure. Urea is the most commonly used N fertilizer denomination by the farmers for rice production, whereas other N P K fertilizers are used for their root and tuber crops production. The use of mineral fertilizers alone has however not been helpful in their agricultural production because it has not led to sustained improved yield. This type of practice and the attendant result (Table 3) could be associated with soil acidity and nutrient imbalances. Urea which is widely used by the farmers is a synthetic fertilizer containing a relatively high (45%) N. Pieri (1992) had discovered that N fertilizers are strongly associated with acidification in the West African region with an average annual increase in Al saturation of 10% and indicated arriving at critical Al toxicity levels of 30% after only a few years of cropping.

Ogbodo 2013 had identified the most serious negative impact associated with acidification in soil that is representative of soils of the study areas as aluminium (Al) and Manganese (Mg) toxicity. At acidic (low pH) values, complexed aluminium, Al (OH), which is common in these soils, is converted to ionic form (Al^{3+}

"exchangeable aluminium"). Ogbodo 2013 showed that rice growth was severely affected by high levels of Al saturation which caused direct injury and deformity to the plant root system. This type of soil constraint has been the cause of low crop productivity in Ebonyi state. Sanchez (1976) had earlier discovered that poor crop growth in acid soils can be directly correlated with aluminium saturation. The other serious negative impact of acidification detected in the area is increased limitation on the availability of P. As a result of the low pH levels, P is complexed with hydrous oxides of iron (Fe) and Al or reacts with silicate minerals. Sanchez 1976 and *Pieri* 1998 have shown that P is most available at neutral pH levels (6-7).

There are still other serious negative impacts to the soil chemistry and the microbial environment which this study has detected. It should be explained on a broader sense that acidification and depletion of nutrients from these soils is a product of not only the application of inorganic fertilizers but of the farmers agricultural practices in general. When crops, and in all cases residues, are removed (soil mining), as is always the practice in this area, this created a deficit in soil organic matter and a parallel decrease in levels of base nutrients and CEC and, therefore, acidification. This process is gradual in comparison to acidification by fertilizers which can be quite rapid with the potential of decimating crop yields in a short period of time. It has also been recorded that crops took up more nutrients when mineral fertilizer was added in what is known as luxury consumption probably because nutrients from this source is readily available (Howeler and Cadavid 1983). Seasonal bush burning which is a prevalent farming practice in the area also contributes substantially to depletion of nutrients from the soils. Padwick, 1983 recognized this when he reported that many African soils show nutrient deficiency problems often only after a short period of cultivation because of their nature as well as prevailing environmental conditions.

The total bacteria and fungi population for the soils seem normal for typical agricultural soils (Table 4). However one must be mindful that the microbial population is rather high for soils of very low organic matter status as observed in the soils.

The results of the microbial isolation have led us to believe that perhaps the microbes are autotrophic, and that are indigenous to the soils of the study locations. The indication could be that the microbes were able to manufacture their own food and sustained their population even under low organic matter levels and very acidic conditions. There could also have been a situation where the microbes were the primary beneficiaries of the applied fertilizer nutrients, that were readily available which they assimilated and achieved growth and multiplication at the expense of the target crops. The microbes assimilated most of the existing soil nutrients to support their own population growth, thereby limiting the amount of nutrients available to support plant growth. These results are consistent with the hypothesis that soil microbes are better competitors for nutrients than are plants (Kaye and Hart, 1997; Hodge et al., 2000). The situation was that when Plants and microbes competed for the same pool of available nutrients, the microbes usually out-competed plants for nutrients.

Countermeasures

The soil acidity and Al toxicity should be normalized with sufficient application of lime to achieve improved crop yields. In view of the nature of the soils, and to ensure sustained crop production to meet the needs of the teaming population, complementary use of organic manure and mineral fertilizers could prove a sound fertility management strategy for these soils. The incorporation of manure and crop residue has been shown to increase the amount of organic matter which are mainly organic acids that increase the rate of desorption of phosphate and thus improve the available P and other nutrients content in the soil (Zsolnay and Gorlitz, 1994 and Ogbodo 2009ab, 2012). High and sustained crop yield had been reported with judicious and balanced NPK fertilization combined with organic matter (kang and Juo 1980).

Conclusion

This study has identified the negative impact of long term input fertilizer applications (used without complementary liming and/or organic amendments) to be primarily acidification. It has shown that the multiple nutrient deficiency problem suffered by the soils studied could be associated with soil acidity and nutrient imbalances. The other negative impact associated with acidification detected by the study is limitation on the availability of P in the soils. However the total bacteria and fungi population for the soils seem normal for typical agricultural soils. The practice of application of lime to the soils and complementary use of organic manure and mineral fertilizers was suggested as a measure of correcting the soils fertility constraints and improving the productivity.

Table 1: Geographical position of the study locations

Study locations	**Geographical location**
Ezzamgbo	No6^{o}2343.77^{1}Eo7^{o}582.65^{1}Alt.105m
Amangwu	No5^{o}499.41^{1}E^{o}70313.24^{1}Alt.77m
Amachi	No6^{o}19.069' E008^{o}11.784' Alt.80m
Akaeze	N05^{o}57.875' E007^{o}33.218' Alt 59m
Oso	No6^{o}59.77^{1}Eo8^{o}1300.44^{1}Alt.38m
Nkalikiunuhu	No6^{o}17.697' E008^{o}05.018' Alt.69m
Umuoghara	N06^{0} 19.829^{1} E008^{0} 03.011' 81m
Ndufu Alike	N06^{0}07.649^{1} E008^{0}19.789^{1} Alt.35m
Umuhuali	N06^{0}30.743^{1} E007^{0}46.115^{1} Alt.100m
Nkalagu	N06^{0}28.675^{1} E007^{0}46.172^{1} Alt.78m
Inyimagu	No6^{o}12.340' E008^{o}11.666' Alt.56m
Ugwulangwu	N06^{o}01.024^{1} E007^{o}49.519^{1} Alt.37m
Uburu	N06^{o}04.399^{1} E007^{o}44.245^{1} Alt.49m
Abaomege	N05^{o}52.599' E007^{o}32.467' Alt.68m
Ukawu	N06^{o}03.413^{1} E007^{o}59.593^{1} Alt.56m

Table 2: Soil texture

Study Sites	Sand %	Silt %	Clay %	Textural Class
Ezzamgbo	69.40	16.4	15.40	Sandy Loam
Amangwu	70.0	10,0	20.0	Sandy Loam
Amachi	74.0	3.2	22.8	SandyClay Loam
Akaeze	18.2	15.0	66.0	Clay
Oso	55	4.0	41.0	Sandy Clay
Nkalikiunuhu	66.0	5.0	29.0	SandyClay Loam
Umuoghara	51.4	12.6	36.0	Sandy Clay
Ndufu Alike	35.4	28.6	36.0	Clay Loam
Umuhuali	74.6	4.4	21.4	SandyClay Loam
Nkalagu	53.4	16.6	30.0	Clay Loam
Inyimagu	67.0	11.0	22.0	SandyClay Loam
Ugwulangwu	65.0	27.0	8.0	Sandy Loam
Uburu	60.0	10.0	30.0	SandyClay Loam
Abaomege	50.0	25.0	25.0	SandyClay Loam
Ukawu	70.0	9.0	23.0	SandyClay Loam

Table 3: Soil chemical properties

Study Sites	**pH (H_2O)**	**P (Mg/g)**	**N (%)**	**OC (%)**	**Ca**	**Mg**	**K**	**Na**	**EA** (Cmol/Kg)	**ECEC**	**BS (%)**
Ezzamgbo	4.6	20.10	0.17	0.51	2.8	1.12	0.10	0.25	0.08	4.18	48.46
Akaeze	4.8	7.8	0.14	0.60	5.10	1.30	0.24	0.10	3.8	6.74	49.63
Amachi	4.3	11.0	0.08	1.04	1.7	0.11	0.10	0.11	2.10	2.02	48.60
Amangwu	4.3	15.4	0.14	0.66	3.1	1.0	0.19	0.21	4.5	4.50	48.81
Oso	4.7	5.7	0.17	1.16	2.3	0.74	0.19	0.22	5.3	3.45	48.35
Nkalikiunuhu	4.10	18.1	0.19	1.0	2.6	0.7	0.11	0.21	2.8	3.62	48.51
Umuoghara	4.5	18.2	0.09	1.93	2.0	1.4	0.27	0.14	0.8	3.81	50.94
Ndufu Alike	4.0	18.1	0.15	1.73	3.6	1.60	0.32	0.17	3.12	5.69	49.24
Umuhuali	5.6	20.9	0.10	1.8	3.62	0.91	0.12	0.16	3.8	4.81	50.85
Nkalagu	5.6	24.1	0.10	1.8	3.6	2.0	0.20	0.14	1.04	5.94	50.60
Inyimagu	4.2	14.0	0.09	1.02	0.86	0.45	0.10	0.20	3.5	0.73	42.06
Ugwulangwu	4.3	17.5	0.13	1.8	1.54	0.92	0.17	0.15	3.1	2.78	48.61
Uburu	4.1	20.0	0.11	1.84	1.4	0.30	0.15	0.11	2.68	1.96	48.56
Abaomege	4.4	12.6	0.13	1.40	1.09	0.36	0.05	0.12	1.40	1.62	48.08
Ukawu	4.3	24.8	0.10	1.4	1.2	0.80	0.32	0.09	3.5	2.41	50.95
Mean	4.52	16.55	0.13	1.31	2.43	0.91	0.18	0.16	2.77	3.55	48.82

Table4: Microbial count of the soils

Sampling zone	Bacteria count (cfu/g)	Fungi count (cfu/g)
Ezzamgbo	$3.01x10^8$	$4.7x10^8$
Amangwu	$4.7x10^8$	$3.17x10^8$
Amachi	$4.81x10^8$	$1.3x10^8$
Akaeze	$5.04x10^8$	$2.11x10^8$
Oso	$6.33x10^8$	$3.9x10^8$
Nkalikiunuhu	$5.78x10^8$	$1.2x10^8$
Umuoghara	$4.73x10^8$	$3.7x10^8$
Ndufu Alike	$2.78x10^8$	$4.7x10^8$
Umuhuali	$3.41x10^8$	$3.0x10^8$
Nkalagu	$3.75x10^8$	$2.9x10^8$
Inyimagu	$5.81x10^8$	$4.1x10^8$
Ugwulangwu	$1.97x10^8$	$1.0x10^8$
Uburu	$4.17x10^8$	$2.3x10^8$
Abaomege	$3.78x10^8$	$2.9x10^8$
Ukawu	$3.71x10^8$	$2.4x10^8$

Key: Cfu/g = colony forming units per gram.

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