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EFFECT OF CHEMICAL FERTILIZER ON SOIL QUALITY IN BOSSO LGA, NIGER STATE, NIGERIA

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Abstract

This study assessed the effects of chemical fertilizers on soil quality in Boso LGA, Niger State, Nigeria; the study investigates the effects of chemical fertilizers (NPK and Urea) usage on the physicochemical and bacteriological properties of the soil. The study was carried out on three sites. Site a represented soil with NPK and Urea Fertilizer usage of 10 years, site represented, soil with NPK and Urea Fertilizer usage of 10 years and site 3 represented the control (i.e. no. NPK and Urea Fertilizer usage). At 5% level of significance, the test of hypothesis showed the following results: Hj: the duration of NPK and Urea Fertilizer application affects the physicochemical properties (pH and Phosphorus) of soil the ANO VA test result indicated that the soil PH decreased with increased NPK and Urea fertilizer usage from site 1 to site 2 while phosphorus increased in site A but decreased in site 2. NPK and Urea increased phosphorus content in site 1but prolonged usage decreased it in site 2. H2: The duration of NPK and Urea fertilizer application significantly affects the bacteriological properties of soil. The findings of the study reveal that the prolonged use of chemical fertilizers (NPK and Urea) adversely affects soil quality. Increased use of NPK and Urea fertilizer *reduces the soil pH thereby making it acidic and unfit for crop production and also reduces the microbial population. Therefore NPK and Urea fertilizer increases the phosphorus content of soil which is a vital nutrient for plant development, however, prolonged application diminishes the amount of phosphorus needed by plant for survival due to soil acidity, and growth of weeds which compete for nutrients with plants and other soil organisms. Continuous chemical fertilizer application in the long run results in poor soil health and nutrient deficiency which negatively affects soil microbial bacteria functions. The typical soil management practices recommended for maintaining a balance in the soil pH value, phosphorous content and microbial bacteria count of the soil include appropriate soil liming, minimal organic manure amendment, Agro-Forestry Practices (alley cropping) and cover cropping and mono cropping.*

Keywords: *Chemical, fertilizer, soil, quality, effect, degradation*

Introduction

Soils have a large function in the health of ecosystem functions in the world, soil is the link between the air, water, rocks, and organisms, and is responsible for many different functions in the natural world that we call ecosystem services. These soil functions include: air quality and composition, temperature regulation, carbon and nutrient cycling, water cycling and quality, natural “waste” (decomposition) treatment and recycling, and habitat for most living things and their food. We could not survive without these soil functions. Soils are the environment in which seeds grow. They provide heat, nutrients, and water that are available for use to nurture plants to maturity. These plants form together with other plants and organisms to create ecosystems. Ecosystems depend on the soil, and soils can help determine where ecosystems are located. These plants then provide valuable habitat and food sources for animals, bacteria, and other things (Schimel 1995). A well covered soil prevents erosion. During times like the great Dust Bowl, wind blows across soils, and suspended them in the air. These are easily inhaled and accumulate in lung tissues causing major respiratory problems. These particles can contain fungi and bacteria, which can cause infection and diseases. They are also important in military operations. Soil temperature plays an important role in many processes, which take place in the soil such as chemical reactions and biological interactions. This includes important processes like seed germination, bugs and microbes that live in the environment, and how quickly plant and animals break down. In colder soils, there is less biological and chemical reactions compared to warmer ones, therefore, there may be more carbon stored in the soils. Agricultural activities such as tillage, intercropping, crop rotation, drainage, use of pesticides and fertilizers have significant impacts on soils and thus affect its functionality; hence sustainable agricultural practices should be adopted. Intensive agricultural management has brought about substantial economic and social development in recent years; it has also contributed to environmental degradation through increased greenhouse gas emissions, biodiversity loss, and reduced delivery of many ecosystem services including soil and water conservation (Kirschenmann, 2010; Moeskops et al., 2010).

Soil contains large amounts of stored carbon, nearly 5 times more than the plants that grow in it. Natural processes are all cyclical. On a global level, the total carbon cycle is more complex, and involves carbon stored in fossil fuels, soils, oceans, and rocks. Physical, biological, and chemical processes in the soil affect the balance in organic carbon compounds, and if they are released to the atmosphere as CU2, or stored in the soil. This same process occurs with Nitrogen, Phosphorus, and all other materials. Without soil and soil particles, water would be running on bare rocks! When it rains, the soil acts as a sponge, soaking water into the ground. From there a few things can happen to the water. The water can be taken up by plants, microbes, and other living things, or the water moves into the underground aquifers and lakes, and flows into streams before eventually making it to the ocean. If rainfall contains harmful pollutants, the soil acts as a filter; contaminants are captured by the soil particles, and the water comes out cleaner in the aquifers and rivers.

Soil filters water as it moves from the land surface into the groundwater. This occurs through physical, chemical and biological process. For example, septic systems rely on these processes to protect groundwater quality as well as maintain the quantity of our water supply. When soils are not protected, soils and nutrients can pollute water, washing away into streams and oceans.

Agricultural production can substantially affect the functioning of ecosystems, both positively and negatively. Growth in global food production over the past half century has required tradeoffs between ecosystem services, resulting in an overall decline in the supply of services other than food and fiber due to higher demand of food n agricultural products from farmers (Millennium Ecosystem Assessment 201 0).In order to meet the demand of the populace and to obtain greater yields per unit time, this demand have led to planting more crops each year ,specializing in recurring cultivation of many varieties, and using higher amounts of external inputs such as chemical fertilizers (Usman and Pingali 2005).

Chemical fertilizer is defined as any inorganic material of wholly or partially synthetic origin that is added to the soil to sustain plant growth. They are manmade soil enhancers added to the soil to promote soil fertility and increase plant growth in a relatively short period of time. They are manufactured synthetically from inorganic material using natural nutrients such as Nitrogen, Phosphorus, and Potassium (NPK).The application of these fertilizers generally improves crop production but is associated with severe environmental problems such as degradation of soil quality, soil acidification which is the buildup of hydrogen cat ions thus reducing the soil pH (Ogbodo, 2013). Bune-mann and McNeill (2004) stated that fertilizers can bring about undesirable changes to the soil chemical environment, and harm to the organisms that come out in contact with the chemicals. Irum (2014) also alludes that the persist ant use of chemical fertilizers causes the pollution of agricultural soil. Jayathilake et al., (2014) further explained that continues use of chemical fertilizers resulted in deficiency of micronutrients, imbalance soil physicochemical properties and unsustainable crop production. The inorganic material in chemical fertilizers adversely affects the health of naturally found soil microorganism by affecting the soil pH. These altered levels of acidity in the soil eliminate the micro —organisms beneficial to plant and soil health as they help to increase the plants natural defenses against pests and diseases. These helpful microorganisms consists of antibiotics — producing bacteria and fungi which are found in healthy soil. The use of chemical fertilizers also jeopardizes the health of bacteria that fix the Nitrogen balance in the soil. These nitrogen fixing bacteria are responsible for converting the atmospheric oxygen into form of nitrogen that can be used readily by plants (United State Department of Agriculture, 2015). Increased crop production largely relies on the type of fertilizers used to supplement essential nutrients for plants. Fertilizer application is required to replace crop land nutrients that have been consumed by previous plant growth with the ultimate goal of maximizing productivity and economic returns. Now a day, there is increased emphasis on the impact on soil environment due to continuous use of chemical fertilizers. The impact of chemical fertilizer application on agricultural land is seen not only in terms of the soil quality but also on the survival of soil organisms dwelling there in. Earthworms are major component of soil fauna in a wide variety of soils and climates and are involved directly or indirectly in biodegradation, stabilization through humus formation and various oil processes. Earthworms represent the greater fraction of biomass of invertebrate in the soil as soil macro fauna and play a vital role in structuring and enhancing plant nutrients and hence they can be successfully used as bio indicators for the evaluation of toxic risks of xenobiotic in terrestrial ecosystems Earthworm populations are influenced by various factors (soil, temperature, moisture, and pH) and the availability of organic matter for food, which may come from plant residues and animal or human waste applied to the land The abundance of earthworms in soils represents the health of soil ecosystems and the level of environmental safety. Application of excess fertilizers, particularly nitrogen and phosphorus, can result in runoff to streams and rivers or contamination of groundwater. In most freshwater systems, phosphorus is the major limiting nutrient for the growth of photosynthetic organisms (e.g., plants, algae, and some microorganisms like phytoplankton). If a lake or pond receives excess phosphate, it can stimulate these organisms, especially if nitrates are present with it. These organisms block out the light and consume oxygen in the water to the detriment of other organisms (e.g., other plants and fish). Other symptoms include cloudy water that is typically green or yellow. Dead plants and fish and cloudy green water make these water bodies uninviting for recreational activities.

Soils are the stomach that converts these "waste" products into newer, better things that can be reused by other creatures. Everything that is living eats, and because of this, everything needs to expel waste products out of their bodies. Humans and other organisms use the soil to decompose these waste materials into new materials. These new materials are used by other living things. Once a living thing dies, it falls into the soil and the biological and chemical processes convert these dead materials into new materials and food for living things. This is nature's way of recycling. Soil supports plant growth and represents the living reservoir that buffers the flow of water, nutrients, and energy through an ecosystem. Soil quality describes soils that are not only fertile but also possess adequate physical, chemical and biological properties to "sustain productivity, maintain environmental quality and promote plant and animal health" (Doran 1994). The measurement of soil quality cannot be done directly but through the use of soil properties as indicators (Brejda et al., 2000).The declining trend in soil quality as a result of fertilizer application is posing a serious threat in soil quality as a result of sustainability of intensive agriculture, causing degradation in form of erosion, deforestation, alkalinity, salinity, acidification, micronutrient deficiency and water logging (Lopez et al., 2011).

Most of the water that people see and use falls first on the land, It then either percolates' to the groundwater, runs over the land surface to a stream or lake, or Moves laterally through the soil to a surface water body. No matter which Route the water takes, the quality of the soil largely determines the chemical and biological characteristics and flow dynamics of the water passing through it. The capacity of a soil to support plant growth and act as a buffer is a Measure of its quality. Soil texture, structure, water-holding capacity, Porosity, organic matter content, and depth are some of the properties that determine soil quality. A soil with sufficient capacity to support one Ecosystem -— rangeland, for example — may not be capable of supporting another such as corn field. Soil quality is important for two reasons. First, we should match our use and management of land to soil capability, because improper use of a soil can damage it and the ecosystem.

Materials and Methods

This research work employed the use of primary and secondary data source. Secondary sources are data gathered through a review of published materials related to the study, while primary sources are data obtained first hand by the researcher from personal observation, laboratory experiments, personal interviews etc. Soil sample was collected randomly from the study area with soil auger and core sampler at various depths from the chemical fertilized farm location and the non-chemical fertilized farm location which served as control for the experiment.

A soil sample is representative sample of the soil from the site which it was collected ten soil samples were collected (five core samples and six composite samples) were collected at two depth (0-15cm and 15-3Ocm)from three (3) different farm sites designated site1 (five years usage duration of NPK and Urea fertilizer), site 2 (l0) years Usage duration of NPK and Urea) and Site C(non- fertilized farm i.e. control site.) were inoculated with soil suspension (O.lml) and stored at 28°C for about 3-5 days (William and Wellington 1982).

Method of Data Analysis

The result of laboratory determination of the physicochemical and bacteriological properties of the soil samples were subjected to statistical analysis.

Results and Discussion

Effect of chemical fertilizer on the physical properties of soil in the study area

The result showed 'that the effects of chemical fertilizer on the soil physical properties shows that at both 0-15cm and 15-30cm depths, site B recorded greatest values for clay (39.02% and 38.98%). Silt had greatest value in site.C at 0-15cm with 39.70% while sand also recorded its highest value in site C at 15-30cm with 36.10%. The soil textural class was clay loam in all 3 sites. Moisture content was highest at 15- 30cm depth in site A with 12.75% and least in site B with 7.66%. At 0-15cm depth, moisture content was highest in site C with 12.75% and least in site B with 8.34 1%. The value for bulk density recorded highest in site A at 15-30cm with I .74g/cm-3 and least in site B with 1.45g/cm-3 (0-15cm) and l.40g/cm3(15-3Ocm). Porosity was highest in site B with 45.28% (0-15cm) and 47.17% (15-30cm). It was lowest in site A with 34.34% (15-30cm).

The result of the effects of chemical fertilizer on the soil chemical-properties showed that soil pH was highest in site C at both 0-15cm and 15-30cm recording 6.60 and 6.30 respectively. It was lowest in Site B at both 0-15cm and 15-30cm recording 4.50 and 4.80 respectively. Site A had the highest Phosphorus content with a value of 51.60mg/kg and 53.90 mg/kg at 0-15cm and 15-30cm respectively. It was lowest in Site B with a value of 29.30mg/kg and 19.00mg/kg at 0-15cm and 15-30cm respectively. Site A recorded the highest and lowest Nitrogen content with a value of 0.70% at 0-15cm- and 0.042% at 15- 30cm. Organic Carbon content recorded highest in site C with a value of 1 .47% at 0-15cm and lowest in site A with a value of 0.32% at 15-30cm. Organic matter content were highest in site C with 2.53% at 0-15cm and lowest in site A with 0.55% at 15-30cm depth.

The results of the effect of chemical fertilizer on soil exchangeable bases (Calcium, Magnesium, Potassium and Sodium), Exchangeable Acidity, Effective Cation Exchange Capacity and Base Saturation shows that Calcium (Ca) concentration was highest in site C with value of ScmoLkg'

(0-15cm) and lowest in site B with value of 3.2Ocmol/kg'(O- 15cm). Magnesium (Mg) concentration was highest in site A with 4.OOcmolfkg' (015cm) and lowest in site B with a 2.O0cmoli'kg' (15-30cm) ranges. Site C recorded the maximum of Potassium (K) concentration with values of 0.22cmoIJkg and 0.2 Icmol/kg at both depths while site B recorded the minimum of potassium with 0. L4cmol kg at 15-30cm. Site B recorded the maximum of Sodium (Na) concentration with 0.29 and 0.3Ocmol kg-i at both depths, while site A recorded the minimum with 0.23cmoI/kg' at 15-30cm. The lowest value for Exchangeable Acidity (EA) was observed in site A with 0.S6cmolIkg' (15-30cm) and the highest in site B with Effective Cation Exchange
Capacity (ECEC) was highest in site C with 13.75cmollkg-l (0-15cm) and. lowest in B with (0-15cm). Percent Base Saturation (BS) was highest in site A with 94.27% (15-30cm) and lowest in site B with 81.67% (0-15cm).

Effects of chemical fertilizer on the bacteriological properties of soil in Study Area

Site	**Depth (cm)**	**Bacteria Count (CFU/g***
1	0-15	8,500,000 (8.5 x 106)
	15-30	9,100,000 (9.1 x 106)
2	0-15	2,900(2.910^{6})
	15-30	31,000(3.1X10^{6})
3	15-30	630,000,000 (5.6x10^{8})
	15-30	56,000.000 (5.6 x 10^{7})

*cfiu/g = colony forming units per gram
Source: Laboratory work, (2021)

An analysis of the effects of chemical fertilizer on soil bacteriological properties as presented in Table above shows that site 3 recorded the highest bacteria count of 630,000,000CFLJ/g and 56,000,000CFU/g at 0-15 and 15-30cm respectively while site 2 recorded the lowest bacteria count of 2,900CFU/g and 31 ,000CFU/gat 0-15cm and 15- 30cm respectively.

Test of Hypotheses

In testing the three hypotheses earlier stated in chapter one, analysis of variance (ANOVA) was used to compare the variance in the physicochemical and bacteriological parameters of soils from sites 1, 2 and 3 at depths of 0-15cm and 15-30cm.

Below are the analyses and the results of the test of hypotheses Hypothesis One

H0: The duration of chemical fertilizer usage does not significantly affect the physicochemical properties of soil in study area.

H1: The duration of chemical fertilizer usage significantly affects the physicochemical properties of soil in the study area.

Decision rule

Accept the alternate hypothesis if p-value is 0.05 otherwise reject and accept the null hypothesis.

Phosphorus:

= 3.243	878.710
= 3.353	945.920
0.967*	0. 929*

The resulting effect size of 0.976 and 0.929 is very large. This implies that the effect of the low pH and phosphorus values of site 1 and 2 is significant.

Therefore, the duration of NPK and urea fertilizer application significantly affects the physicochemical properties of soil in study area. The null hypothesis Ho was rejected and the alternative H_1 accepted.

Hypothesis Two

H0: The duration of chemical fertilizer usage does not significantly affect the bacteriological properties of soil in study area.
H1: The duration of NPK and urea fertilizer application significantly affects the bacteriological properties of soil in study area, one-way ANOVA was performed using the data in table above.

Decision Rule
Accept the alternate hypothesis if p-value is 0.05 otherwise reject and accept the null hypothesis.

	Sum of Squares	Df		F	Sig.
Between	3296.0000	2	7646805151	1.393	.373
Groups Within	4992.000	3	5491272679		
Total	8320.000				

Robust Test of Equality of Means
Bacteria Count

	Statistic[al]	Df1	Df2	Sig.
NPK and	285.770	2	1.336	.017
Urea Control	1.393	2	1.000	.514

a. Asymptotically F distributed

Conclusion
Indicators of soil quality measured to assess the condition of soils in study area varied across the sampling sites with respect to combined use of NPK and Urea fertilizer usage duration and soil depths. The analyzed values of these soil quality indicators were compared to the values at a control site.

The result from this study showed that the application of NPK fertilizer made no significant change in soil texture (sand, silt and clay),moisture content, bulk density, total porosity, organic carbon, organic matter, total nitrogen, soil exchangeable bases (Calcium, Magnesium, Potassium and Sodium), Exchangeable Acidity, Effective Cation Exchangeable Capacity and Base Saturation in site 1, 2 and3. However, there was significant change in soil pH and phosphorus content with respect to site 1, 2 and 3. There was a decrease in the soil pH value in site 1 and 2compared to site 3; the application of chemical fertilizer decreased their pH values. The application of NPK and Urea fertilizer in site 1 and 2 reduced the soil pH value which is the most important indicator of soil quality with regard to crop production because low pH which indicates acidic soil seriously affects crop growth, production and its physiological activities. Soil bacteria count also decreased with increased duration of NPK and Urea fertilizer application. Soil bacteria count was highest in site 3 (control) because there was no fertilizer application. Site 2 recorded the least bacteria population because NPK and urea fertilizer was applied for 10 years while site 1recorded a higher population of soil bacteria than 2 because NPK and Ureafertilizer was applied for 5 years. This signifies that the duration of chemical fertilizer application significantly affects the bacteriological characteristics of the soil in the study area. NPK and Urea fertilizers contain ingredients which when dissolved in the soil kills microbes such as bacteria that help in proper decomposition of organic matter which the plant use for their physiological functions. Although application of chemical fertilizer has positive effect on the crop growth, on the long run, its application and method of application and soil management approach can affect nutrient availability and also change soil properties.

This study indicates that the application NPK and urea fertilizers can decrease soil pH level and equally reduces soil bacteria. However, further research should include assessment of soil biological indicators such as fungi, actinomycetes and other biological indicators that might be affected by NPK and Urea fertilizer application and also soil sample size in each selected farm lands should be many, this will provide more information about the status of soils in study area.

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