DETERMINATION OF NITRATES, SULPHATES AND PHOSPHATES IN SOIL OF OGOBIRI AND ADAGBABIRI FARMLANDS IN BAYELSA STATE, NIGERIA

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Abstract: The natural medium in which most plants' roots develop is soil. Most farmers experience issues in the quality of goods acquired from specific farms over time owing to a lack of understanding about the necessity for soil testing or the usage of fertilizers for crop development. On the farmlands of Agbadabiri and Ogobiri Villages in Bayelsa State, Nigeria, nitrate, sulphate, and phosphate levels were measured. For three months, samples were obtained using an auger at various depths (from 10 cm to 30 cm). For the measurement of NO_3^-, SO_4^{2-}, and PO_4^{3-} in soil samples and control, a standard spectrophotometer was set at 470 nm, 420 nm, and 660 nm, respectively. The mean and standard deviation of the soil samples tested in various batches were calculated using Microsoft Excel. With a probability of 0.05 acceptance, a one-way ANOVA was utilized to assess the significant difference between the samples and the control. In the Ogobiri and Adagbabiri villages, the ranges in nitrate (3.25ppm–4.66ppm), sulphate (2.55ppm–5.25ppm), and phosphate (0.67ppm–3.98ppm) were found for both farmlands and control. The results revealed that nutrient concentrations were below standard, necessitating the application of fertilizer to boost nutrient availability.

1. INTRODUCTION

Soil is one of the most essential substrata of life on Earth, acting as a store of water and nutrients, a filter and breakdown mechanism for harmful wastes, and a participant in carbon and other elements cycling across the global ecosystem. It's a biologically active, porous material that's formed in the Earth's crust's highest layer. The plant collects water and solutes from the soil in order to maintain its health. All of the chemical ingredients essential for plant development are easily available in fertile soil (Samira et al., 2009).

Figure 1.1 showing a typical soil

According to Balasubramanian (2017), soil is a complex mass containing mineral matter derived from the disintegration and decomposition of rocks, organic matter derived from the decay of plant residues, animal remains, and microbial tissues.
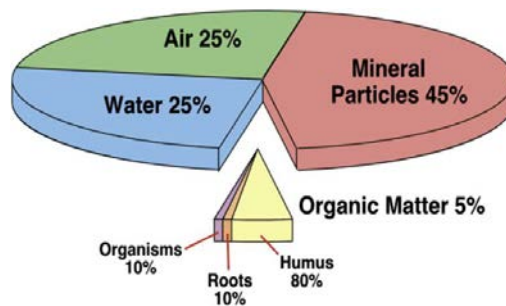

Figure 1.2 showing soil makeup by percentage (Balasubramanian, 2017)

Soil is a primary source of nutrients that plants require for growth. Nitrogen (N), phosphorus (P), and potassium (K) are the three most important nutrients in soil. According to Weier, Stocking, and Barbour (1973), large amounts of phosphate and nitrogen are necessary. Plants take up phosphorus in the form of phosphate ions (HPO_4^{2-} and HPO_4^{-}) from the soil solution. (Stevenson & Cole, 1999; Brady & Weil, 2008). Most farmers, due to a lack of knowledge about the need for soil testing or the use of fertilizers for crop production, face challenges in the quality of product obtained from a particular farmland over time. On the other hand, when nutrients in the soil become excessive, nutrient uptake can also cause poor growth because of toxicity. As a result, the need for the proper application of nutrients is imperative.

This research aimed to study the nitrate, sulphate, and phosphate ions in the farmlands of Agbadabiri and Ogobiri villages in Bayelsa State, Nigeria. According to Haygarth and Ritz (2009), soil functions as a major component of the earth's ecosystem and takes up and releases important gases, including oxygen and greenhouse gases, in a process called gas regulation. The conservation, restoration, and optimization of ecosystem services provided by soils is among the greatest challenges for humanity in the 21st century.
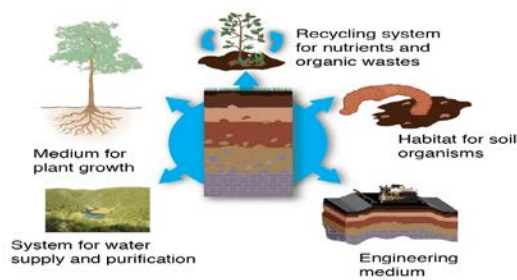
Figure 1.3 Soils as ecosystem service providers (Needelman, 2013)

As shown in Fig. 1.3, soil serves as an engineering medium, a habitat for soil organisms, a recycling system for nutrients and organic wastes, a regulator of water quality, a modifier of atmospheric composition, and a medium for plant growth, making it a critical provider of ecosystem services, according to Dominati, Patterson, and Mackay (2010). A gram of soil can contain billions of organisms, belonging to thousands of species, mostly microbial and largely unexplored (Dykhuizen, 1998; Torsvik, Øvreås, 2002). Soil has prokaryotic organisms *(*Raynaud, and Nunan, 2014) and the ocean *(*Whitman, Coleman, and Wiebe, 1998*)*. Organic carbon stored in soil is eventually released into the atmosphere via the process of respiration carried out by heterotrophic organisms, although a significant portion is kept in the soil as soil organic matter (Schlesinger and Andrews, 2000). The water-holding capacity of soils is vital for plant survival (Denmead and Shaw, 1962).

House, Bergmann, Stomp, and Frederick (1999), reviewed that soils can effectively remove impurities, kill disease agents, and degrade contaminants, the latter property being called natural attenuation (EPA, 2012), which was credited to Van Bruggen and Semenov (2000). Typically, soils maintain a net absorption of oxygen and methane and undergo a net release of carbon (IV) oxide and nitrous oxide (Linn and Doran, 1984). Soils offer plants physical support, air, water, temperature moderation, nutrients, and protection from toxins (Miller and Donahue, 1990; Bot and Benites, 2005). Soil consists of a solid phase of minerals and organic matter as well as a porous phase that holds gases and water (Voroney & Heck, 2007; Taylor and Ashcroft, 1972). Soil scientists can visualize soils as a three-state system of solids, liquids, and gases (McCarthy, 2006). Soil has about 45% mineral, 5% organic matter and 50% pores, of which half is occupied by water and half by gas (McClellan, 2021). Percentages of soil mineral and organic content can be treated as quatities, whereas soil water and gas content are deliberated variable, whereby a rise in one is instantaneously balanced by a decline in the other (AMGM, 2017). The pore space permits the permeation and movement of air and water, both of which are critical for life existing in soil *(Vannier, 1987)*. Compaction of soil reduces space, blocking air and water from reaching plant roots and soil organisms (Torbert & Wood 1992). (The Mosaic Company, 2021) described, the particle size dispersal for texture and relative to the surrounding components. According to Blum, Schad, and Nortcliff (2018), a soil horizon is the result of soil-forming processes. The living component of the soil is largely confined to the solum and is generally more prominent in the A horizon (Simonson, 1957).
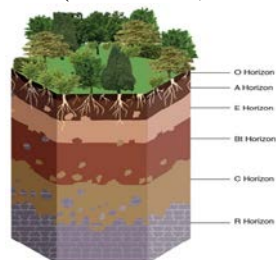

Figure 1.4 showing different soil horizon

Each horizon has its own characteristic properties. (Needelman, 2013).

Water is a critical agent in soil development (FAO, 1985). Water affects the type of vegetation that grows in a soil, which in turn affects the development of the soil, a complex feedback which is embodied in the changing aspects of stripy vegetation patterns in semi-arid regions *(Valentin, d'Herbès, & Poesen, 1999)*.

There are 12 orders of soils categorized by the U.S. Department of Agriculture.

Table 1. Orders in Soil Taxonomy

Alfisols: found in areas with low rainfall, but wetter than deserts
Andisols: found in volcanic ash
Aridisols: found in deserts
Entisols: young soils (develop in recently active areas, such as floodplains and mountains)
Gelisols: develop in very cold climates, with permafrost near the surface
Histosols: soils very rich in organic matter, common in wetlands
Inceptisols: fairly young soils, but with more soil development than Entisols
Mollisols: found in grasslands (such as the Midwestern prairies), have thick, dark, fertile soil
Oxisols: old soils formed in the tropics, have very low fertility
Spodosols: generally, develop in temperate coniferous forests, have very low fertility
Ultisols: form in humid temperate and tropical regions in older landscapes, are highly acidic with low fertility
Vertisols: soils rich in clay, which causes them to swell when wet and shrink (causing large cracks) when dry

The physical properties of soils, in order of diminishing prominence for ecosystem such as crop production, are texture, structure, bulk density, porosity, consistency, temperature, colour, and resistivity *(Gardner, Laryea, & Unger, 1999)*. Most of these properties determine the aeration of the soil and the ability of water to gain access and be held within the soil *(Tamboli, 1961)*. According to College of Tropical Agriculture and Human Resources (CTAHR) (2007), Soil texture is the fractions of sand, silt, or clay in a soil. An acre of living topsoil contains approximately 900 pounds of earthworms, 2,400 pounds of fungi, 1,500 pounds of bacteria, 133 pounds of protozoa, 890 pounds of arthropods and algae, and even small mammals in some cases. (Pimentel, 1995). Boundless selection of organisms has impact on soil fertility.
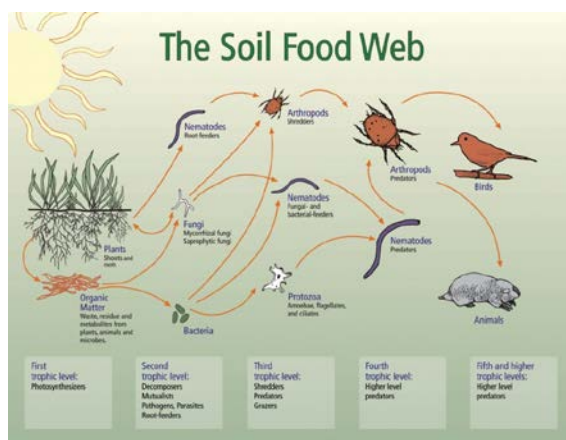

Figure 1.5. Soil Food Web.

Vertically, earthworm burrows pipe air deeper into the soil, stimulating microbial nutrient cycling at deeper levels. (Edwards, Clive and Bohlen, 1996). Nutrient elements obtained from the soil are

Nitrogen, Phosphorus, Potassium, Sulphur, Magnesium, Calcium, Iron, Boron, Manganese, Zinc, Molybdenum, Copper (CTAHR, 2007).
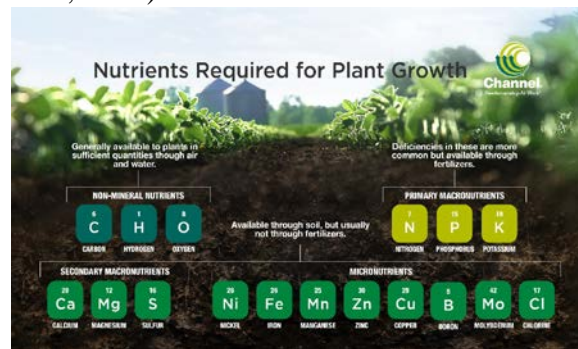

Figure 1.6 18 nutrients in soil

Macronutrients expected for plant growth are primary nutrients and intermediate nutrients. The primary nutrients are nitrogen, phosphorus and potassium. The intermediate nutrients are sulphur, magnesium**,** and calcium. Phosphorus is required in the same amount as the intermediate nutrients, despite being a primary nutrient.

Figure. 1.7 Macronutrients in soil

 Micronutrients, such as Fe, Mn, Cu, Zn, and Ni are taken up by plants in their cationic forms, and B, Mo, and Cl are taken up by plants in their anionic forms (Ginder-Vogel & Sparks 2010). Limited evidence suggests that B species (i.e., $B(OH)_3$ and $B(OH)_4$) in soils are adsorbed by forming inner-sphere complexes on the surfaces of Fe and Al oxides (Su & Suarez, 1995).
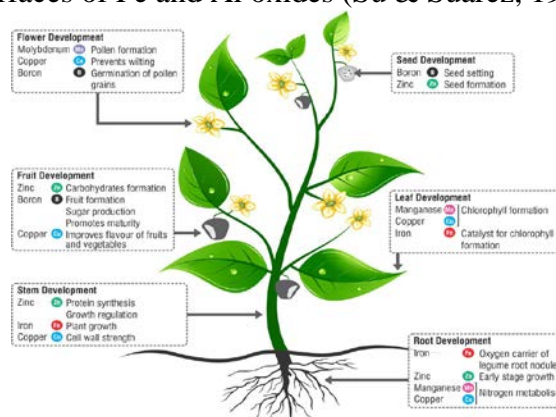

Figure 1.8 Functions of micronutrients in plants.

Table 2 Plant nutrients, their chemical symbols, and the ionic forms common in soils and available for plant uptake (*Donahue 1977*).

Element	Symbol	Ion or molecule
Boron	B	H_3BO_3, $H_2BO_3^-$, $B(OH)_4^-$
Calcium	Ca	Ca^{2+}
Carbon	C	CO_2 (mostly through leaves)
Chlorine	Cl	Cl^- (chloride)
Copper	Cu	Cu^{2+}
Hydrogen	H	H^+, HOH (water)
Iron	Fe	Fe^{2+}, Fe^{3+} (ferrous, ferric)
Magnesium	Mg	Mg^{2+}
Manganese	Mn	Mn^{2+}
Molybdenum	Mo	MoO_4^{2-} (molybdate)
Nitrogen	N	NH_4^+, NO_3^- (ammonium, nitrate)
Oxygen	O	O^{2-}, OH^-, CO_3^{2-}, SO_4^{2-}, CO_2
Phosphorus	P	$H_2PO_4^-$, HPO_4^{2-} (phosphates)
Potassium	K	K^+
Sulfur	S	SO_4^{2-}
Zinc	Zn	Zn^{2+}

Soil nitrate is an exceptional pointer of nitrogen-cycling in soils to whether leftover nitrogen used by the previous crop or additional nitrogen is needed (USDA, 2014).
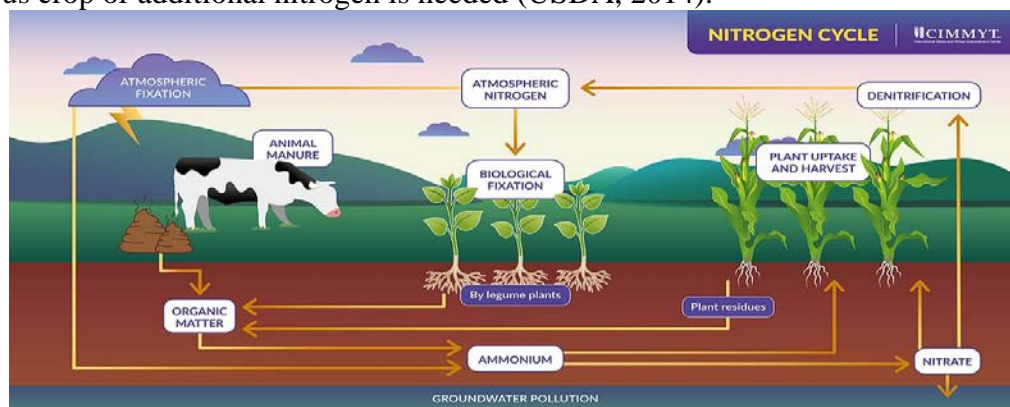

Figure 1.9 A diagram shows the process through which nitrogen moves from the atmosphere to earth, through soils and is released back into the atmosphere – converting in and out of its organic and inorganic forms. (Graphic: Nancy Valtierra/CIMMYT) Nitrogen Cycle.

Nitrogen processes in soils are carried out by microbes to harvest energy, for microbial growth, or for plant use (USDA, 2014). Photosynthesis occurs at high rates when there is sufficient nitrogen (CTAHR, 2007). According to Heather, (2019), nitrogen deficiencies usually appear as yellowing on older or minor leaves of the plant and stunted growth.

Figure 1.10 Nitrogen deficient plant

When algae die, their decomposition results in oxygen depletion which can lead to the death of aquatic plants and animals. This process is called "eutrophication" (Charles *et al.,* 2005).

Phosphorus exists in many different forms in soil such as Organic Phosphorus, Adsorbed Phosphorus, and Primary mineral Phosphorus (Charles *et al.,* 2005).

However, the phosphorus cycle is by no means less complex than the nitrogen cycle, as shown in fig. 1.11, and there are many factors that affect the availability of phosphorus in the soil (CTAHR, 2007). In comparison to other macronutrients, the phosphorus concentration in the soil solution is much lower and ranges from 0.001 mg/L to 1 mg/L(Brady and Weil, 2008).
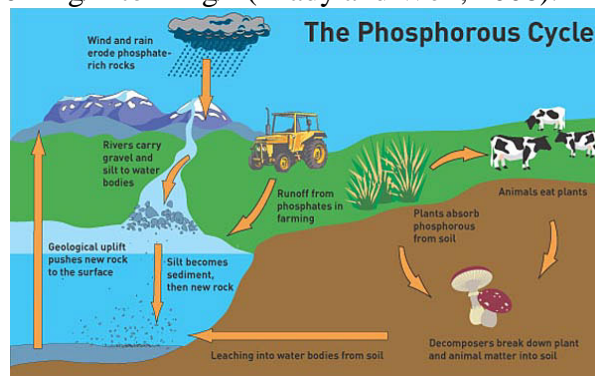

Figure 1.11 Phosphorus cycle

Phosphorus may be lacking if you see dull yellow foliage or slow overall plant growth. When absent, plant will not grow properly (Heather, 2019).

Figure 1.12 Phosphorus deficient leaf

Sulphur is an essential nutrient for Oil crops, legumes, forages, and some vegetable crops (Smart Fertilizer, 2020). Enquiry on Sulphur sensing, uptake, assimilation, and functional properties has increased (Weissert & Kehr, 2017). Sulphur deficiency symptoms may resemble nitrogen deficiencies; growth may be stunted, with spindly and thin stems (CTAHR, 2007).

Figure 1.13 Sulphur deficiency in corn

2. SAMPLE COLLECTION

Three soil samples were collected from different places in the farmland of Adagbabiri and Ogobiri villages, both in the Sagbama Local Government Area of Bayelsa State, Nigeria. The Ogobiri community is located close to the Niger River, while the Adagbabiri community is located close to the Forcados river.
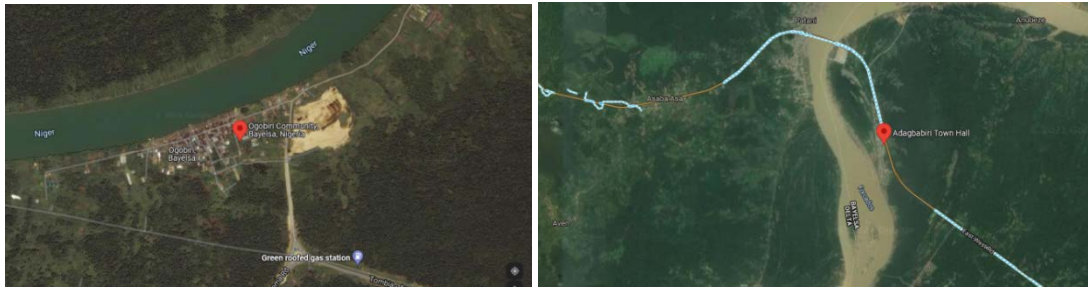

Figure 2.1. Ogobiri community and Adagbabiri community respectively. (Source: Makar Technologies; Map data ©2021

The samples were collected by using an auger at different depths (from 10 cm to 30 cm). The auger is suitable for sampling hard soils. It consists of a sharpened spiral blade attached to a central metal rod, which can be screwed into the soil. The auger was screwed to the desired depth and the sample was withdrawn. Soil samples were transferred to plastic bags and labeled. The symbols O_a, O_b, and O_c were given for soil samples gotten from the Ogobiri community, with a, b, and c representing soil depths of 10 cm, 20 cm, and 30 cm, respectively. Another three symbols, A_a, Ab, and Ac, were given for soil samples gotten from the Adagbabiri community with a, b, and c, also representing soil depth at 10 cm, 20 cm, and 30 cm, respectively.

2.1   SAMPLE PREPARATION

The samples were taken to the laboratory and air-dried; grass and any external objects were removed. After rolling the samples to break down the large masses of soil particles, sieving was done using a mechanical sieving apparatus, which consists of different sizes of mesh. The sieved samples were then preserved in their respective cleaned and labeled plastic bags for further analysis.

2.2   METHOD FOR SOIL ANALYSIS
2.2.1   Determination of pH

The samples were taken to the laboratory and air-dried; grass and any external objects were removed. After rolling the samples to break down the large masses of soil particles, sieving was done

using a mechanical sieving apparatus, which consists of different sizes of meshes. The sieved samples were then preserved in their respective cleaned and labeled plastic bags for further analysis.

2.2.2 Determination of Electrical Conductivity of the Sample Soil

In the filtrate described in 1 above, the conductivity probe was inserted and the meter switched over to the conductivity mode. A steady readout from the meter is recorded as the conductivity of the soil sample

2.2.3 Determination of Nitrate (NO3-)

Preparation of extracting solution: 50 g of sodium acetate was dissolved in 250 mL of distilled water in a 1 L flask. Then, 30 mL of Conc. acetic acid was added to the solution. This was made up to 1 liter with distilled water. 5 g of salt was weighed into a shaking bottle. 1/2 spatula full of activated charcoal was added to the bottle, followed by 20 mL of extracting solution. The bottle was shaken for two (2) minutes and later filtered. 1 mL of the filtrate was transferred to a test tube, followed by 0.5 l of NO_3^- reagent (brucine) and 2 mL of H_2SO_4. These were mixed for 30 seconds and allowed to stand for 5 minutes. A further 2 mL of distilled water was added and mixed again. The test-tube was allowed to cool for 15 mins. The spectrophotometer was set at 470nm and the absorbance by extrapolation from a standard nitrate curve. (Grewelling and peech 1965)

2.2.4 Determination of Sulphate (SO42-)

Preparation of the extracting solution: 0.5 g of $KH_2PO_4.2H_2O$ in 1 liter of water.
5 g of dried and sieved (2 mm) soil samples were weighed into a 250 mL conical flask and 25 mL of extracting solution was added. This was agitated on the mechanical shaker for 10 minutes. The suspension was filtered and 10 mL of the filtrate was transferred into a 25 mL volumetric flask. Some distilled water was added to bring the volume to 20 mL. 1mL of 10% $BaCl_2$ was then added and the final volume was made up to the mark. The mixture was shaken for 30 minutes. The spectrophotometer was set at 420 nm, and the transmittance was determined, and the concentration of SO_4 was obtained by extrapolation of a standard SO_4 laboratory graph (Tabataba, 1974).

2.2.5 Determination of Phosphate (PO43-)

Extracting solution; for phosphate determination was prepared by adding, 15 mL of 1.0 M ammonium fluoride solution into a 500 mL volumetric flask, 460 mL of distilled water was added to the flask and made up to the mark. 1 g of air-dried soil sample was weighed into a centrifuge tube and 7 mL aliquots of the extracting solution were transferred into the tubes, which were placed on the orbital shaker and shaken for five (5) minutes. The tubes were then placed in the centrifuge machine and centrifuged at 2000 rpm for 10 min. 2 mL of aliquots of the clear supernatant were transferred into boiling tubes. 5 mL of distilled water and 2 mL of ammonia solution were added and mixed by shaking the tubes.
Finally, 1mL aliquots of stannous chloride were added to the tubes and mixed. The spectrophotometer was set at 660 nm. Absorbance values were taken. The amount of phosphate in the soil was determined from the standard curve and was preferred with standard phosphate solutions. (Bray and Kurtz; Jackson, [1965, 1962])

2.3   STATISTICAL ANALYSIS

Data analysis was carried out using Microsoft Excel 2007 software to calculate the mean and standard deviation, while one-way ANOVA with Stats Tester software was used in assessing the significant differences among the control and soil samples. Significance was accepted at a 0.05 level of probability.

3. RESULTS AND DISCUSSION
3.1   Soil Sample and Control result for Ogobiri Community

Tables 3.1 to 3.3 below show soil sample and control test results for three months at different soil depths in the Ogobiri community.

Table 3.1. Mean and Standard Deviation ($\pm$) of Control, NO_3^-, SO_4^{2-} and PO_4^{3-} of Soil Samples Collected From Ogobiri Farmland in September

Parameters	10cm	20cm	30cm	Control
NO_3^-	3.76 ± 0.02	3.90 ± 0.02	4.20 ± 0.02	2.99 ± 0.56
SO_4^{2-}	4.16 ± 0.02	3.95 ± 0.01	4.40 ± 0.02	3.80 ± 0.02
PO_4^{3-}	2.96 ± 0.02	2.75 ± 0.01	2.35 ± 0.02	1.80 ± 0.02

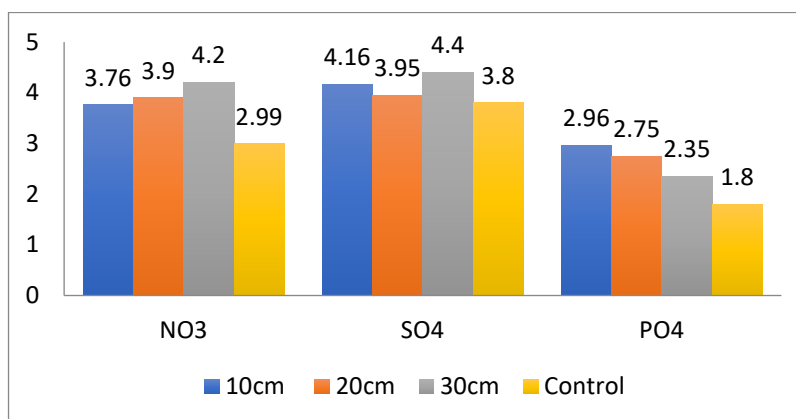*Mean and Standard Deviation ($\pm$) of three replicate analysis.*

Figure 3.1. Graph showing the level of NO_3^-, SO_4^{2-} and PO_4^{3-} in soil samples and control at Ogobiri in September

Table 3.2. Mean and Standard Deviation ($\pm$) of Control, NO_3^-, SO_4^{2-} and PO_4^{3-} of Soil Samples Collected From Ogobiri Farmland in October

Parameters	10cm	20cm	30cm	Control
NO_3^-	3.25 ± 0.02	3.54 ± 0.02	3.80 ± 0.02	3.76 ± 0.02
SO_4^{2-}	2.56 ± 0.02	2.86 ± 0.01	2.96 ± 0.02	3.86 ± 0.01
PO_4^{3-}	1.50 ± 0.02	1.54 ± 0.02	1.65 ± 0.01	1.56 ± 0.02

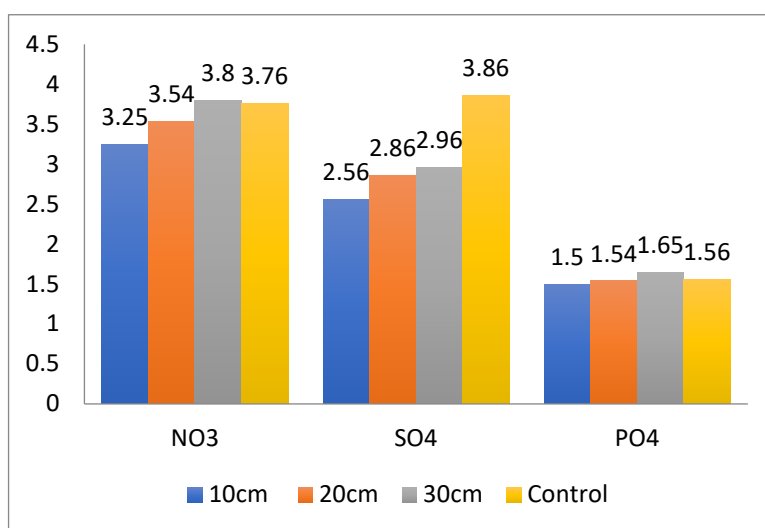*Mean and Standard Deviation ($\pm$) of three replicate analysis.*

Figure 3.2. Graph showing the level of NO_3^-, SO_4^{2-} and PO_4^{3-} in soil samples and control at Ogobiri in October

Table 3.3. Mean and Standard Deviation (±) of Control, NO_3^-, SO_4^{2-} and PO_4^{3-} of Soil Samples Collected From Ogobiri Farmland in November

Parameters	10cm	20cm	30cm	Control
NO_3^-	3.36 ± 0.02	3.60 ± 0.02	3.47 ± 0.02	4.4 ± 0.02
SO_4^{2-}	2.80 ± 0.02	2.82 ± 0.02	2.95 ± 0.02	5.25 ± 0.01
PO_4^{3-}	1.72 ± 0.02	1.90 ± 0.02	2.10 ± 0.02	3.92 ± 0.02

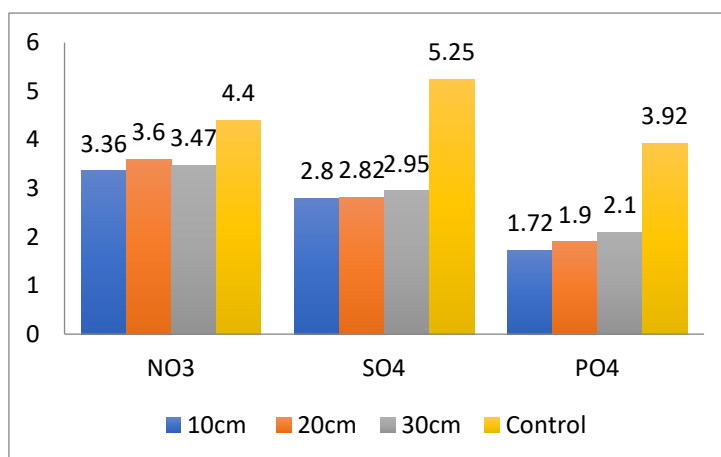*Mean and Standard Deviation (±) of three replicate analysis.*

Figure 3.3. Graph showing the level of NO_3^-, SO_4^{2-} and PO_4^{3-} in soil samples and control at Ogobiri in November

3.2 Soil Sample and Control result for Adagbabiri Community

Tables 3.4 to 3.6 below show soil sample and control test result for three months at different soil depths in Adagbabiri Farmland.

Table 3.4. Mean and Standard Deviation (±) of Control, NO_3^-, SO_4^{2-} and PO_4^{3-} of Soil Samples Collected From Adagbabiri Farmland in September

Parameters	10cm	20cm	30cm	Control
NO_3^-	4.24 ± 0.02	3.86 ± 0.02	3.40 ± 0.02	3.68 ± 0.02
SO_4^{2-}	2.85 ± 0.02	2.75 ± 0.01	2.55 ± 0.02	2.90 ± 0.04
PO_4^{3-}	0.67 ± 0.03	0.83 ± 0.02	0.76 ± 0.02	1.20 ± 0.02

Mean and Standard Deviation (±) of three replicate analysis.

Figure 3.4. Graph showing the level of NO_3^-, SO_4^{2-} and PO_4^{3-} in soil samples at Adagbabiri Farmland and control in September.

Table 3.5. Mean and Standard Deviation (±) of Control, NO_3^-, SO_4^{2-} and PO_4^{3-} of Soil Samples Collected From Adagbabiri Farmland in October

Parameters	10cm	20cm	30cm	Control
NO_3^-	3.96 ± 0.02	4.10 ± 0.02	4.40 ± 0.02	3.68 ± 0.02
SO_4^{2-}	3.2 ± 0.02	3.77 ± 0.02	3.90 ± 0.02	4.26 ± 0.02
PO_4^{3-}	0.74 ± 0.02	0.95 ± 0.01	0.88 ± 0.02	1.46 ± 0.01

Mean and Standard Deviation (±) of three replicate analysis.
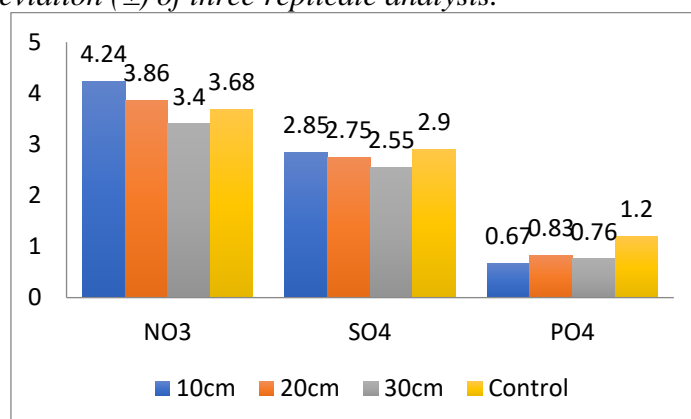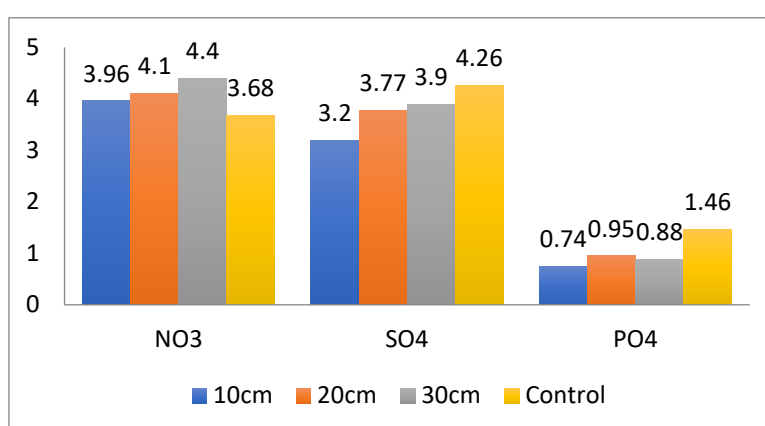

Figure 3.5. Graph showing the level of NO_3^-, SO_4^{2-} and PO_4^{3-} in soil samples at Adagbabiri Farmland and control in October

Table 3.6. Mean and Standard Deviation ($\pm$) of Control, NO_3^-, SO_4^{2-} and PO_4^{3-} of Soil Samples Collected From Adagbabiri Farmland in November

Parameters	10cm	20cm	30cm	Control
NO_3^-	4.30 ± 0.02	4.54 ± 0.02	4.66 ± 0.02	3.45 ± 0.02
SO_4^{2-}	4.21 ± 0.04	5.25 ± 0.02	4.40 ± 0.02	4.60 ± 0.02
PO_4^{3-}	0.86 ± 0.01	0.84 ± 0.02	0.78 ± 0.02	3.48 ± 0.02

Mean and Standard Deviation ($\pm$) of three replicate analysis.
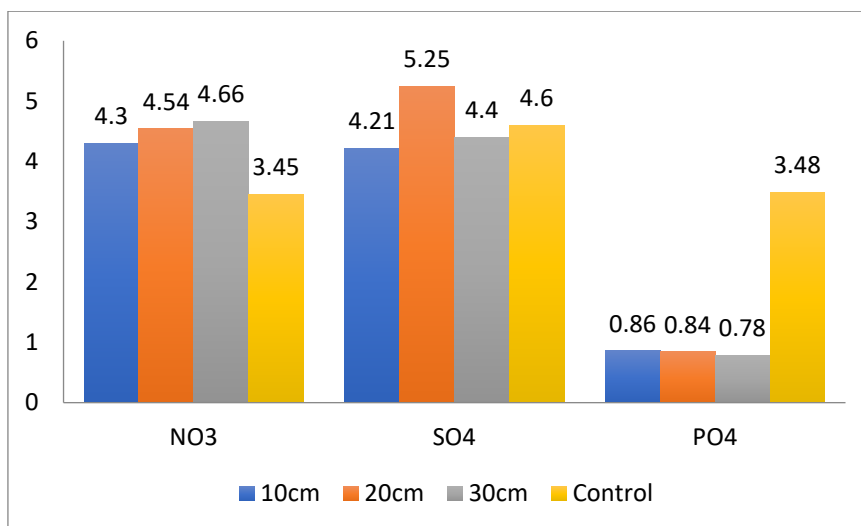

Figure 3.6. Graph showing the level of NO_3^-, SO_4^{2-} and PO_4^{3-} in soil samples at Adagbabiri Farmland and control in November

3.3   DISCUSSION

3.3.1   Soil and Control Sample Analysis in Ogobiri Community from September to November

The results are in table 3.1 and figure 3.1, which shows that there is no significant difference ($p = .075$) between the nitrate level in the control and the soil sample at 10 cm. The result also shows a significant difference ($p = .05$) between the nitrate level in the control and the soil sample at 20 cm. The soil sample and control at 30 cm also showed a significant difference ($p = .02$) in nitrate levels. There were significant differences ($p = .00002$, $p = .000314$, and $p = .000003$) between the sulphate level in the control and the soil sample at 10 cm, 20 cm, and 30 cm, respectively. The level of sulphate at 20 cm was lower than that at 10 cm. The phosphate level in Ogobiri farmland showed a significant difference between the control and the soil samples at 10, 20 and 30 cm with a level of probability of $p .05$. At various depths, the phosphate level was seen to be lower than that of the nitrate and sulphate levels. The data also shows that the amount of phosphate in the soil decreased as the depth increased from 10 to 30 cm.

The result from table 3.2 shows that there was a significant difference between nitrate, sulphate, and phosphate levels in the control and soil sample at 10 cm as all had a probability of $p 0.05$ ($p = .000006$, $p = 0$, and $p = .000052$ for NO_3^-, SO_4^{2-} and PO_4^{3-} respectively). The soil sample and control at 20 cm showed a significant difference ($p = .0002$) in nitrate levels between the control and soil sample. It also showed a significant difference ($p = 0$) between sulphate levels in the control and soil samples in the farmland at 20 cm depth. There was, however, no significant difference ($p = 0.288$) between phosphate levels in control and soil samples. The results also showed that the nitrate levels in the

control and soil samples at 30 cm approached the borderline of significance (p =.07). There was a significant difference ($p = 0$), however, between the levels of sulphate in the control and soil samples at 30 cm. Also, the amount of phosphate in the control and the soil sample at 30 cm showed significant differences ($p =.00226$) between them. It was also observed that the amount of phosphate in Ogbobiri farmland was lower than that of nitrate and sulphate. The data also showed that as the depth increased, the level of nitrate and sulphate concentrations increased. However, the increment in sulphate levels at various depths was way below the amount of sulphate in the control.

The result in table 3.3 showed that there was a significant difference ($p = 0$) in the means between the control and soil sample for nitrate at 10 cm. There were also significant differences ($p =.000001$) in the means of nitrate at 20 cm and 30 cm between the control and soil samples. The results also revealed a significant difference ($p.05$) in the means for sulphate at 10 cm, 20 cm, and 30 cm between the control and soil samples result was seen for phosphate levels at 10 cm, 20 cm, and 30 cm. The level of phosphate increased as the depth increased. The values of phosphate, however, were lower than those recorded in September and slightly higher than the values in October.

3.3.2 Soil a nd C ontrol Sa mple A nalysis i n A dagbabiri C ommunity f rom Se ptember t o November

The results in table 3.4 show that there was a significant difference (p =.000004) in the mean nitrate level between the control and soil sample at 10 cm. The result also showed a significant difference in the means (p =.000385) at 20 cm and (p =.000068) at 30 cm between the control and soil samples. However, there was a decrease in the amount of nitrate as the depth increased. The amount of nitrate concentration in the control was within the range of soil samples at various depths. The results also showed that the sulphate levels in the control and soil samples at 10 cm approached the borderline of significance in the means (p =.07). There were significant differences ($p =.003436$) at 20 cm and ($p =.000187$) at 30 cm for sulphate concentrations between the control and soil samples. The sulphate level dropped slightly as the depth increased from 10 cm to 30 cm. The amount of phosphorus in the control and soil samples at 10 cm appeared to have significant differences ($p=.000015$) in the means. There was also a significant difference ($p =.000022$ and $p=.000011$) in the means at 20 cm and 30 cm, respectively. The phosphorus levels in Adagbabiri were way too low compared to the nitrate and sulphate levels.

Table 3.5 revealed that there were significant differences ($p=.000068$, $p =.000014$, and $p =.000002$) in the means for the amount of nitrate between the control and soil samples at 10 cm, 20 cm, and 30 cm, respectively. There were also significant differences ($p =.000001$, $p =.000007$ and $p=.000025$) in the means for the amount of sulphate between the control and soil samples at depths of 10, 20, and 30 cm, respectively. The data shows that both nitrate and sulphate levels in soil samples increased as the depth increased. According to the data in table 3.5 and figure 3.5, there was a significant difference (p.05) in the means for the amount of phosphate in the Adagbabiri community in October between the control and soil samples at depths of 10, 20, and 30 cm, respectively.

The results in table 3.6 show that there was a significant difference ($p<0.05$) in the mean nitrate level between the control and soil samples at 10, 20 and 30 cm depths. There were also significant differences ($p<0.05$) in the means for the amounts of sulphate and phosphate between the control and soil samples at depths of 10, 20, and 30 cm, respectively. The level of nitrate in the soil at various depths was shown to have increased slightly and was higher than the control in the Adagbabiri community. The amount of phosphate in the control was way higher than the amount found in the soil samples at various depths. However, the amount of phosphate in the soil showed a slight decrease. Phosphorus deficiencies can cause poor fruit and seed development as well as delayed crop maturity (CTAHR, 2007). It can also make older leaves develop a dark green to blue-green colour.

3.3.3 Comparison of Obtained Results with Other Studies

The concentration of phosphate in this study was higher than the values obtained by Amponsah *et al.* (2014), which reported 1.159 ppm as its highest for cropped land. The soil test analysis conducted by research on a variety of crop growing soils gave values of 12-20 ppm of phosphate, which is regarded to be adequate for plant establishment and production. All the samples found in this study as well as the control are phosphate deficient as values are below the critical level of 5 mg/Kg as stated by Wani *et al*., (2011) and Rajaskhekha *et al*., (2010). As seen from the results in this study, Phosphorus concentration is usually low in a typical soil solution compare to that of Nitrogen and Potassium, and the low availability of natural phosphorus. These make phosphorus one of the major limiting nutrients for plant growth in the humid tropics (Amponsah *et al.,* 2014). This study also recorded a lower amount of phosphate compared to nitrate and sulphate radicals found in soil samples and control. The value of sulphate in this study was way below values obtained by Amponsah *et al.* (2014), who reported the highest value in cropped land to be 43.3 ppm and 14.8 ppm in uncropped land (control). However, this study only met with the lowest values reported by Mesoppirr *et al.* (2015). Soil test analysis gave standard sulphate values required for growth to be between 15 and 40 ppm. This is the concentration of sulfate expressed in ppm that is sufficient for plant growth. The nitrate level in this study from September to November were very low compared to values reported by Dennis and John (2003), Vanek et al., (2003) and Heckmann (2003) whose values were above 10mg/kg. The results obtained in this study showed lower amounts of NO_3^-, SO_4^{2-} and PO_4^{3-} in Ogobiri and Adagbabiri farmlands when compared to results obtained by Samira et al., (2009) for sulphate (9.0 – 256.0 mg/L), phosphate (0.58-3.39 mg/L) and nitrate (1.24-1107.73 mg/L). Only phosphate concentrations in this study matched those in this report. The low concentrations of NO_3^-, SO_4^{2-} and PO_4^{3-} in Ogobiri and Adagbabiri farmland show that the application of fertilizer has not been adopted by farmers overtime.

4.0 CONCLUSION AND RECOMMENDATION

4.1 CONCLUSION

Soil is a major source of nutrients required by plants for growth, and fertile soil contains all the chemical elements essential for plant growth in readily obtainable form. This study focused on the three main nutrients (nitrate, sulphate, and phosphate radicals) in the farmlands of Adagbabiri community and Ogobiri village, Bayelsa State, Nigeria. The result showed that the level of phosphate in soil samples and control for both communities was lower than the nitrate and sulphate. The result gotten from this study is an indication that farmers do not apply fertilizers on their farmland before planting crops, thereby having a shortage of the essential plant nutrients.

4.2 RECOMMENDATION

The following are recommendations after carrying out this study:
(I) Awareness should be given to farmers on the need for soil testing to ascertain the level of nutrients in farmland.
(II) Farmers should also employ the use of fertilizers for crop production in order to increase the amount of nutrients in the soil in order to obtain a quality yield.

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