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# Soil Fertility Analysis in Two Cocoa Farming Towns in the Central Region of Ghana

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**Abstract:** Our soil resource can be compared to a bank where continued withdrawal without repayment cannot continue indefinitely. As nutrients are removed by one crop and not replaced for subsequent crop production, yields will decrease accordingly. Accurate accounting of nutrient removal and replacement, crop production statistics, and soil analysis results will help the producer manage fertilizer applications. Macronutrients, micronutrients, pH and salinity were determined in soil samples from two cocoa farming towns in Assin North District in the Central Region of Ghana. Neutron Activation method was used for the elemental analysis. The pHs from both towns were within the acidic range and from both towns also salinity increased with depth. For the soil samples from Assin Akonfudi potassium concentration was the highest and molybdenum was the least in the soil. For the soil samples from Assin Bereku potassium recorded the highest concentration and molybdenum recorded the least concentration in the soil.

**Key words:** Macronutrients, micronutrients, pH, salinity and neutron activation analysis

## INTRODUCTION

Cocoa has been grown in Ghana since the middle 19th Century. Cocoa was first exported at the end of the 19th Century, and between 1911-1976 Ghana was the world's leading producer, contributing between 30-40% of the world's total output. There are currently around 1.6 million people involved in growing cocoa and many more in associated industries. Due to the importance of cocoa in Ghana, both in terms of its effect over the lives of these cocoa farmers and to the Ghanaian economy therefore the need for this project (Anonymous, 2010a).

Agricultural land is primarily required for the production of food for human and animal consumption, agricultural activities also include the growing of plants for fiber and fuels (including wood), and for other organically derived products (pharmaceuticals, etc.,) for use by humans and his animals (Kenk and Cotic, 1983; Hounkonnou *et al*., 2006).

One of the most important natural resources that cover much of the earth's surface is soil. Most life on earth depends upon the soil as a direct or indirect source of food. Plants are rooted in the soil and obtain nutrients from it. Animals also get nutrients from eating the plants on the soil. Soil is home of many organisms such as seeds, spores, insects, and worms. The contents of soil change constantly and there are many different kinds of soil. It forms very slowly and is destroyed easily, so it must be conserved in order to continue to support life (Anonymous, 2010b).

The study of the soil has been fostered by people's interest in plant growth and food production. (Hinrich *et al*., 1985) The ability to produce food is the fundamental factors in societal development therefore need to know the kind of element or nutrient for a better production (Saïdou *et al*., 2004).

Our soil resource can be compared to a bank where continued withdrawal without repayment cannot continue indefinitely. As nutrients are removed by one crop and not replaced for subsequent crop production, yields will decrease accordingly. Accurate accounting of nutrient removal and replacement, crop production statistics, and soil analysis results will help the producer manage fertilizer applications.To grow good crops, most farmers need to fertilize the soil. Fertilizing increases crop yield, and the improved crop growth maintains and even builds soil structure and the quality of the soil. If things aren't done properly, however, there can be negative impacts," says Ross McKenzie, agronomy research scientist with Alberta Agriculture and Food, Lethbridge. "Over

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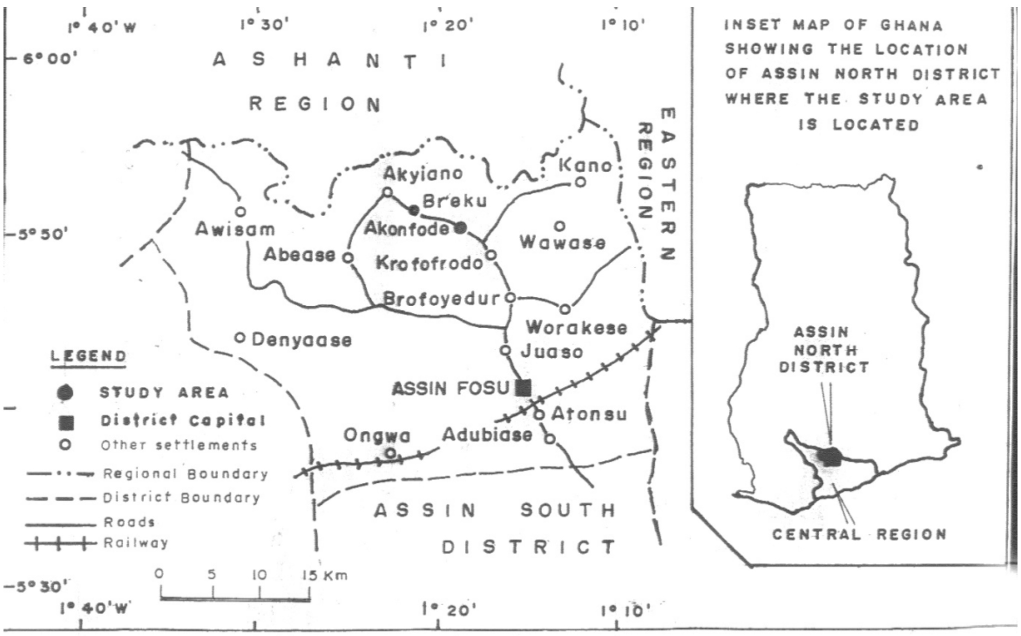


SOURCE: ASSIN NORTH DISTRICT ASSEMBLY – ASSIN FOSU

Fig. 1: The map of Assin North District showing Assin Akonfodi and Assin Berekum as the study area

fertilizing with nitrogen, for instance, can potentially lead to nitrate leeching into the ground water or erosion can cause phosphorus to enter surface water. Environmental considerations and the high cost of nitrogen and fertilizers have made it even more important for farmers to use good management practices. Soil analysis is used to determine the level of nutrients found in a soil sample. As such, it can only be as accurate as the sample taken in a particular field. The results of a soil analysis provide the agricultural producer with an estimate of the amount of fertilizer nutrients needed to supplement those in the soil (Baker *et al*., 1956; Adjei-Nsiah *et al*., 2004).

High yields of top-quality crops require an abundant supply of 19 essential nutrient elements which are classified into four groups which are:

- Major non-mineral macronutrients: these are 90-95% of dry plants weight and are supplied to the plant by water adsorption and photosynthesis are carbon (C), hydrogen (H), oxygen (O).
- Primary macronutrients are nitrogen (N), phosphorus (P) and potassium (K).
- Secondary macronutrients are calcium (Ca), magnesium (Mg) and sulfur (S).
- Micronutrients are boron (B), chlorine (Cl), cobalt (Co), copper (Cu), iron (Fe), manganese (Mn), zinc (Zn) and molybdenum (Mo) (Stanley, 1995).
- Beneficial elements in the soil that are sodium (Na), and selenium (Se) (Samuel *et al*., 1985).

Of these nutrients only 11 will be studied that is potassium (K), calcium (Ca), magnesium (Mg), chlorine (Cl), cobalt (Co), copper (Cu), iron (Fe), manganese (Mn), zinc (Zn), molybdenum (Mo) and sodium (Na).

The main aim of this study is to determine the amount of nutrients found in the soil sample so as to provide the agricultural producer with an estimate amount of fertilizer nutrients needed to supplement those in the soil.

**Study area:** The area chosen under this study was the Assin North District. The Assin North District is among the thirteen (13) districts of the Central Region of Ghana. It lies within Longitudes 1º05′ E and 1º25′ W and Latitudes 6º05′ N and 6º40′ S (Fig. 1).

Assin North District falls within the moist tropical forest, mainly deciduous forest. The area has an annual rainfall between 1500 to 2000 mm. Annual temperatures are high and range between 30ºC from March to April and about 26ºC in August. Average relative humidity is high ranging from 60 to 70%.

The District is characterized by undulating topography and has an average height of about 200 m above sea level. Flood-prone plains of rivers and streams lay low below sea level.

The land area is underlain by geological strata of Cape Coast Granite Complex belonging to the pre-Cambrian Platform. It comprises basically granites, grandiosities and adamellites. It is schistose in some communities and very massive in others. It also includes several components ranging in composition from grandiorites to granites and their migmatitic varieties. The predominant mica minerals are muscovite and biotite. 60% of the communities however are underlain by the lower Birrimian Phyllites, which are often associated with extensive decomposition basins and thick weathering mantles (Ghana Districts website).

## MATERIALS AND METHODS

**Sampling:** The soil samples were collected from Assin Akonfodi and Assin Bereku in the Assin North District during the month of August to September 2009. Soil samples of (0-5 cm) depth, (5-30 cm) depth, and (30-40) depth were taken from these farms. Each sample comprised of composite of 5 sub samples taken across a 5×5 $m^2$. The samples were collected with a hand auger (a stainless steel screw) and hand spade and transferred into a clean polyethylene bags to avoid any contaminations. 15 samples were taken from each farm.

**Sample preparation:** The samples were then brought to the laboratory and then air dried for 72 h (3 days) and the desaggregated, sieved to 0.5 mm. The fine soil was used for analysis. One hundred milligrams (100 mg) of each of these fine samples were weighed onto ultra clean polyethylene sheets wrapped nicely and heat sealed. Each sample was weighed thrice; one to be for short lived nuclides, the second for medium-lived nuclides and the last for the long-lived nuclides. The samples weighed for medium-lived and long-lived nuclides were packed into rabbit capsules (they were packed as many as the capsule could contain) and heat sealed for irradiation. The samples weighed for short lived nuclides on the other hand were packed singly into rabbit capsules (stocking the space left in the rabbit capsule with cotton wool to make sure that the sample does not move in the capsule) and heat sealed for irradiation. Some were also used to check for the pH and salinity of the soil since they play an important row to absorption of nutrients by plants.

**Reference material:** Two certified standard reference soil materials SOIL-7 and GBW07106 were similarly prepared, weighed and heat sealed for irradiation. The certified reference materials were used as quality control to validate the analytical technique.

**Sample irradiation, counting and analysis:** Irradiation of the samples was done using the Ghana Research Reactor-1 (GHARR-1) facility operating at half power of 15kW and at a neutron flux of $5.0\times10^{11}$ neutrons /$cm^{2\text{-}s1}$. The scheme for irradiation was chosen according to the half-lives of the elements of interest, samlpe metrix and the major elements present.

Radionuclides with half-lives ranging from seconds to minutes were given short irradiation of 10 s. Radionuclides with half-lives ranging from hours to about 3 days were given medium time of irradiation of 1 h. Radionuclides with half-lives above the medium category received long irradiation for 6 h.

Samples given short irradiation were allowed to decay for a limited period of time before the gamma spectral intensities were measured to determine the elemental compositions. The gamma spectral intensities for medium and long half-life radionuclides were also measured after 2 days and between 2-4 weeks decays period, respectively.

After irradiation, the samples were counted for 10 min for both short and medium and 10 hours for the long radionuclides on a PC-based gamma-ray spectrometry system. The spectrometry system consists of High Purity Germanium (HPGe) N-type coaxial detector, an Ortec Multi-Channel Analyzer (MCA) emulation software card and a Pentium II computer for spectrum and data evaluation and analysis. During counting, the samples were placed at a distance of 7.2 cm from the surface of the detector. The areas under the photopeaks of the identified elements were integrated and converted into concentration using the single relative comparator method.

## RESULTS

**Validation of the analytical methods:** The results were validated using IAEA-Soil-7 and GBW 07106 Certified Reference Material as shown in Table 1 and 2. The experimental data compared favourably well with the certified data.

Table 1: Analysis of IAEA-soil-7 by INAA

| Element | This study | Certified values |
|---|---|---|
| K | 12090±363 | 12100±363 |
| Ca | 163009±4890 | 163000±4890 |
| Mg | 11306±339 | 11300±339 |
| Cu | 18±0.54 | 11±0.33 |
| Mn | 639±19 | 631±18 |
| Mo | 3.1±0.09 | 2.5±0.08 |
| Na | 247±7 | 240±7 |

Table 2: Analysis of GBW07106 by INAA

| Element | This study | Certified values |
|---|---|---|
| Cl | 50±10 | 44±9 |
| Cu | 15±1 | 19±2 |
| Mn | 147±9 | 155±10 |
| Mo | 0.99±0.22 | 0.76±0.21 |

Table 3: Average concentrations and concentration ranges (mg/kg) of elements at various depths in soil from a Cocoa Farm in Assin Akonfudi (AAEC)

| | Average concentrations at various depths in soil | | | Concentrations ranges at various depths in soil | | |
|---|---|---|---|---|---|---|
| Element | 0-5 cm | 5-30 cm | 30-40 cm | 0-5 cm | 5-30 cm | 30-40 cm |
| K | 20843.80±1042 | 20709.44±1035 | 19361.42±968 | 18621.75-22567.53 | 16805.52-23033.77 | 14860.83-24667.76 |
| Ca | 3880.51±194 | 2830.29±142 | 2398.36±119 | 2598.32-4846.91 | 1057.48-4604.42 | 1012.73-4433.10 |
| Fe | 1814.20±91 | 2118.60±106 | 2723.00±136 | 1235.00-2321.00 | 1229.50-2764.00 | 909.50-3953.50 |
| Na | 5673.25±284 | 5350.33±268 | 4350.59±218 | 3934.12-8685.80 | 2793.74-9598.05 | 2487.59-7654.94 |
| Mn | 104.41±5.22 | 85.18±4.26 | 60.38±3.02 | 38.30-154.60 | 27.65-113.35 | 23.35-71.95 |
| Mg | 33.26±1.67 | 26.30±1.32 | 23.18±1.14 | 25.70-50.00 | 16.80-40.90 | 18.10-34.70 |
| Zn | 3.48±0.17 | 3.05±0.15 | 4.38±0.22 | 0.40-6.55 | 0.40-5.25 | 0.15-8.30 |
| Cu | 5.80±0.29 | 6.57±0.33 | 8.39±0.42 | 3.65-7.00 | 3.00-9.40 | 1.95-13.25 |
| Cl | 11.20±0.56 | 6.03±0.30 | 18.34±0.92 | 4.16-20.48 | 3.51-9.11 | 4.98-52.01 |
| Co | 1.40±0.07 | 1.96±0.10 | 2.23±0.11 | 0.30-2.55 | <0.005-4.55 | <0.005-4.50 |
| Mo | 0.21±0.01 | 0.26±0.01 | 0.60±0.03 | <0.01-1.05 | <0.01-0.93 | <0.01-2.27 |

Table 4: Average concentrations and concentration ranges (mg/kg) of elements at various depths in soil from a Cocoa Farm in Assin Breku (BBC)

| | Average concentrations at various depths in soil | | | Concentration ranges at various depths in soil | | |
|---|---|---|---|---|---|---|
| Element | 0-5 cm | 5-30 cm | 30-40 cm | 0-5 cm | 5-30 cm | 30-40 cm |
| K | 24237.46±1212 | 23353.43±1168 | 19886.61±994 | 16601.11-36096.83 | 18290.12-35025.99 | 15305.52-28591.19 |
| Ca | 5004.40±250 | 7093.89±355 | 8574.66±876 | 3726.22-6723.02 | 5087.88-8885.86 | 1848.14-17524.33 |
| Fe | 1623.70±81 | 1076.50±116 | 2970.40±149 | 1083.50-2272.50 | 1076.50-2843.50 | 2006.00-3627.50 |
| Na | 10500.17±525 | 10095.31±505 | 9345.07±467 | 6317.42-14030.44 | 4594.10-17117.98 | 3651.47-20344.50 |
| Mn | 106.17±5.31 | 74.67±3.73 | 66.86±3.34 | 84.65-116.80 | 56.15-88.00 | 48.10-89.95 |
| Mg | 42.90±2.15 | 40.88±2.04 | 41.70±2.09 | 30.00-75.40 | 22.60-85.90 | 21.80-88.20 |
| Zn | 4.73±0.24 | 5.01±0.25 | 6.68±0.33 | 3.20-6.65 | 3.40-7.45 | 5.10-8.20 |
| Cu | 4.51±0.22 | 7.77±0.39 | 10.26±0.51 | 0.85-8.15 | 1.15-12.85 | 4.20-14.00 |
| Cl | 19.00±0.95 | 67.20±3.36 | 37.45±1.87 | 11.05-30.56 | 18.52-164.42 | 10.89-102.33 |
| Co | 2.84±0.14 | 2.65±0.13 | 3.05±0.15 | 1.50-4.45 | 2.00-3.30 | 2.20-4.55 |
| Mo | 0.70±0.04 | 0.87±0.04 | 0.69±0.03 | <0.01-2.20 | <0.01-2.48 | <0.01-2.32 |

Table 5: pH of samples taken from the two cocoa farms

| | Average pH at various depth | | | pH ranges at various depth | | | |
|---|---|---|---|---|---|---|---|
| Sample name | 0-5 cm | 5-30 cm | 30-40 cm | 0-5 cm | 5-30 cm | 30-40 cm | Preferred pH |
| AAEC | 5.88 | 5.79 | 5.60 | 5.54-6.08 | 5.35-6.01 | 5.12-6.02 | 5-5.5 |
| BBC | 5.47 | 5.26 | 5.16 | 5.16-5.89 | 5.13-5.48 | 5.01-5.55 | |

Table 6: Salinity of samples taken from the two cocoa farms

| | Average salinity at various depth | | | Salinity ranges at various depth | | | |
|---|---|---|---|---|---|---|---|
| Sample name | 0-5 cm | 5-30 cm | 30-40 cm | 0-5 cm | 5-30 cm | 30-40 cm | Preferred salinity |
| AAEC | 1.88 | 2.02 | 2.04 | 1.56-2.10 | 1.87-2.15 | 1.81-2.33 | 0-2 |
| BBC | 2.24 | 2.56 | 2.60 | 2.3-2.56 | 2.32-2.98 | 2.14-3.01 | |

**Concentrations of the nutrient studied from the two cocoa farms:** The average concentrations values measured in the soil at the various depths in the two cocoa farms are presented in Table 3, while the average concentrations values in the soil at the various depths from the two cocoa farms are presented in Table 4.

**pH and salinity values:** The average pH values measured in the soil at the various depths in the two cocoa farms are presented in Table 5, while the average salinity values in the soil at the various depths from the two cocoa farms are presented in Table 6.

**pH and salinity values:** The average pH values measured in the soil at the various depths in the two cocoa farms are presented in Table 5, while the average salinity values in the soil at the various depths from the two cocoa farms are presented in Table 6.

## DISCUSSION

The pH and salinity are as shown in Table 5 and 6. Although the pH of the sample falls within acidic range, the pH of the top soil (0-5 cm) were slightly higher than those of the sub soils, at the depth of 5-30 cm and 30-40 cm. pH of soil samples at the depth of 5-30 cm were also slightly higher than those at the depth of 30-40. In all the pH decreased as the depth increased.

The average pH of soil samples from cocoa farm in Assin Akonfudi (AAEC) were 5.88 at 0-5 cm, 5.79 at

5-30 cm and 5.60 at 30-40 cm which were all higher than the preferred pH and ranged from 5.54-6.08 at 0-5 cm, 5.35-6.01 at 5-30 cm and 5.12-6.02 at 30-40 cm as shown in Table 5.

The average pH of the soil samples from cocoa farm in Assin Bereku (BBC) were 5.47 at 0-5 cm, 5.26 at 5-30 cm and 5.16 at 30-40 cm which were all within the preferred pH and ranged from 5.16-5.89 at 0-5 cm, 5.13-5.48 at 5-30 cm and 5.01-5.55 at 30-40 cm as shown in Table 5.

For the salinity, the top soil (0-5 cm) were slightly lower than that of the sub soils, that was those at the depth of 5-30 cm and 30-40 cm. Salinity of soil samples at the depth of 5-30 cm was also slightly lower than those at the depth of 30-40. In all the salinity increased as the depth also increased.

The average salinities of the soil samples from cocoa farm in Assin Bereku (BBC) were 2.24 (dS/m) at 0-5cm, 2.56 (dS/m) at 5-30cm and 2.60 (dS/m) at 30-40 cm which were all above the preferred salinity of soil and ranged from 2.23-2.56 (dS/m) at 0-5cm, 2.32-2.98 (dS/m) at 5-30 cm and 2.14-3.01 (dS/m) at 30-40 cm as shown in Table 6.

The concentrations of elements in soil from cocoa farm in Assin Akonfodi are as shown in Table 6. Of the elements potassium (K) recorded the highest concentration in the soil and molybdenum (Mo) recorded the least concentration in the soil as shown in Table 3.

From the average concentrations, potassium (K), calcium (Ca), sodium (Na), manganese (Mn) and magnesium (Mg) concentrations in soil decreased as the depth in soil increased. These elements were highest in 0-5 cm and lowest at 30-40 cm as shown in Table 3.

From the average concentrations, iron (Fe), copper (Cu), cobalt (Co) and molybdenum (Mo) concentrations in soil rather increased as the depth in soil increased. These elements were highest at 30-40 cm and lowest at 0-5 cm as shown in Table 3.

From the average concentrations of zinc (Zn) and chlorine (Cl) in soil were highest at 30-40cm depth and lowest at 5-30 cm depth as shown in Table 3.

The average concentrations and the range concentrations of the various elements in the soil samples from Assin Akonfodi Cocoa farm is as shown in Table 3.

The concentrations of elements in soil from cocoa farm in Assin Breku are as shown in Table 4. Of the entire element potassium recorded the highest concentration in the soil and molybdenum recorded the least concentration in the soil.

From the average concentrations, potassium, sodium and manganese in soil decreased as the depth in soil increased. These elements were highest in 0-5 cm and lowest at 30-40 cm as shown in Table 4.

From the average concentrations, calcium, zinc and copper in soil rather increased as the depth in soil increased. These elements were highest at 30-40 cm and lowest at 0-5 cm as shown in Table 4.

From the average concentrations, iron and cobalt in soil were highest at 30-40 cm depth and lowest at 5-30 cm depth and chlorine, concentration in soil was highest at 5-30 cm and lowest at 0-5 cm depth as shown in Table 4.

From the average concentrations, magnesium (Mg) concentration in soil was highest at 0-5 cm depth and lowest at 5-30 cm depth and molybdenum concentrations in soil were highest at 5-30 cm and lowest at 30-40 cm as shown in Table 4.

The average concentrations and the range concentrations of the various elements in the soil samples from Assin Breku cocoa farm was as shown in Table 4.

The cocoa farm soil at Assin Breku recorded the highest concentrations of the nutrients as compared to that of the soil from Assin Akonfodi except for Mg where the concentrations at 5-30 cm depth of soil from Assin Akonfodi was higher than that of soil from Assin Breku and also Cu where the concentration at 0-5 cm depth of soil from Assin Akonfodi was higher than that of soil from Assin Breku.

## CONCLUSION

INAA with conventional counting system has been used to analyze soil samples from cocoa farms from both Assin Akonfodi and Assin Bereku in the central region. The concentrations of K in soil samples from both farms were far above the preferred concentration needed for plants growth (i.e., 100-400 mg/kg (Rai, 1977; Robinson, 1976) and this may be due to the geology of the place which is rich in mica.

In the same way the concentrations of Fe and Mn in soil from both farms were also higher than the preferred concentrations needed for plant growth (i.e., 50-250 and 10-50 mg/kg, respectively (Rai, 1977; Robinson, 1976) and this may also be due to the geology of the place which is rich in Birrimain phyllites and mica. But for Mn the concentration only becomes toxic to plants when the concentration exceeds 300 mg/kg (Doberman and Fsirhurst, 2000) which the concentrations from soil from both farms fell below.

For Ca and Na the concentrations in soil from both farms were also above the preferred concentration needed for plant growth (i.e., 20-100 and 1-1000 mg/kg, respectively (Rai, 1977; Robinson, 1976).

For Mg, the soil from cocoa farm from Assin Akonfodi were within the preferred concentration needed for plant growth but the soil from Assin Bereku was slightly above the preferred concentration (i.e., 10-40 mg/kg (Rai, 1977; Robinson, 1976)).

For Cu all the concentrations in soil from both farms were within the preferred concentration needed for plants growth except concentration of soil at 0-5 cm from Assin Bereku which was slightly below the preferred concentration (i.e., 5-20 mg/kg (Rai, 1977; Robinson, 1976)).

For Zn, Mo and Co, all the concentrations in soil from both farms were within the preferred concentration needed for plants growth (i.e., 2.5-150, 0.02-5 and 0.02-5 mg/kg, respectively (Rai, 1977; Robinson, 1976)).

For Cl, all the concentrations in soil from both farms were slightly below the preferred concentration needed for plant growth except of concentrations in soils at 5-30 and 30-40 cm depths from Assin Bereku which were within the preferred concentration (i.e., 20-200 mg/kg (Rai, 1977; Robinson, 1976)).

The soil pH and salinity were all normal range and will not have any adverse effect on plants.

From the results obtained it is recommended that no fertilizer be added to the soil as at now since all the nutrient needed for plant growth were at an appreciable concentration or even more. Any addition of nutrient to the soil could bring problems to the plants.

With this result more studies can be extended to other regions where farming is one of the major occupations for a better yield.

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