UNIVERSITY OF DAR ES SALAAM

UNIVERSITY OF DAR ES SALAAM INNOVATION AND ENTREPRENEURSHIP CENTER (UDIEC)

PROJECT TITLE

ASSESMENT OF SOIL NUTRIENTS STATUS AND DEVELOPMENT OF SITE SPECIFIC NUTRIENTS MANAGEMENT TOOL FOR CASHEW FARMING IN SOUTH-EASTERN TANZANIA

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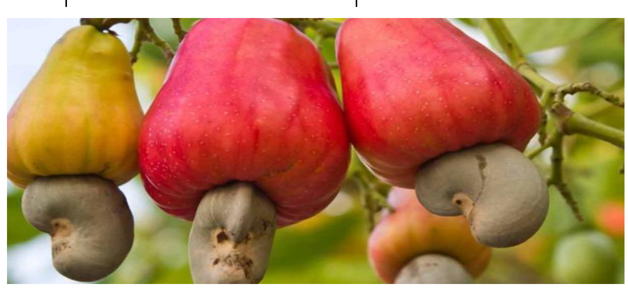

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Abstract

The main objective of the present project was to develop a site specific nutrients management tool for cashew farming system in South Eastern Tanzania. To achieve the objective, three sites were identified to represent the study area (Naliendele, Nanyanga and Nachingwea). From each site soil fertility in terms of both physical and chemical parameters was determined to understand the fertility status so as to facilitate the development and calibration of the tool.

Methodology and results: Soil and cashew nut leaves samples were collected from the three sites namely Naliendele, Nanyanga and Nachingwea. Samples were prepared according to standard procedures described by Allen Stewart (1989) and American Soil Science Society (1994). They were then analyzed for physico-chemical characteristic. Thus soil test involved the determination of chemical and physical characteristics to determine their nutrient contents, organic matters, CEC, EC and textural classes. Overall, results show that soils were Sandy-Loam in texture and were deficient in Potassium, available Phosphorus, Calcium, Organic matter/Carbon Cation Exchange Capacity and Nitrogen content for growing cashew.

Conclusions and application of findings: Result after analysis showed that soil physical characteristics were excellent in all site. Most soil exhibited same loam which had good aeration, excellent rooting capacity but low nutrient holding capacity. The low clay and organic matter content of the soils had negative influence on the soil's fertility status.

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List of Abbreviations

Symbol	Meaning
AAS	Atomic absorption spectrophotometer
AC4	Anacardium Celyon
AZA2	Anacardium Zanzibar
Ca	Calcium
CEC	Cation exchange capacity
CLNB	Cashew Leaf and Nut Blight
CNSL	Cashew Nut Shell Liquid
CoET	College of Engineering Technology
CoICT	College of Information and Communication Technologies
CoNAS	College of Natural and Applied Sciences
EC	Electro conductivity
K	Potassium
Mg	Magnesium
N	Nitrogen
Na	Sodium
NARI	Naliendele Agricultural Research Institutes
OC	Organic Carbon
OM	Organic Matters
P	Phosphorus
PSG	Polyclonal Seed Garden
PT	Practical Training
TN	Total Nitrogen

UDIEC	University of Dar es salaam Innovation and Entrepreneurship Center

1.0 **INTRODUCTION**

1.1 Background

Cashew nut (*Anacardium occidentale*) is a native crop to Latin America and has a primary centre of diversity in Amazonia, and a secondary one in Brazil. It belongs to Anacardiaceae family which contains some 60 to 74 genera and 400 to 600 species. The genus of cashew is *Anacardium* and a species epiphet is *occidintale.* The diagnostic features of Anacardiaceae family are presence of resinous conduct in the cortex and wood where resine is formed, also exudates occur from leaves, flowers, and fruits (Kapinga & Kasuga, 2011). Natural occurrence of cashew has been reported from Mexico to Peru, and in the west of India. It was one of the first fruit tree from the new world to be widely distributed throughout the tropics by the early Portuguese and Spanish adventurers. The name cashew is from the Portuguese *caju*, which in turn comes from the Tupi-India word *acaju*. The incoming colonists in what is now Brazil found that the native Indians valued both the cashew nut and the so-called apple, the fleshly pedicel or stalk of the fruit (Kapinga & Kasuga, 2011).

Cashew was discovered by Portuguese traders and explorers in Brazil in 1578. It was introduced into west and east Africa and India by the Portuguese travellers in the 16th century. By then, cashew was considered as suitable crop for soil conservation, forestation and also wasteland development. Therefore the initial aim of cashew introduction to those areas was not to produce nuts and apple (pseudo-fruits) but to help control soil erosion on the coast (Bradkte, 2007)

Use of cashew nut and apple developed much later and the international nut trade did not start until the 1920s. Thereafter, cashew gradually gained commercial importance and spread in other places. It is now naturalized in many tropical countries, particularly in coastal areas of East Africa (Tanzania, Kenya, Mozambique, Uganda Mauritius, Seychelles,and Madagascar), West and Central Africa (Ivory Coast, Nigeria and Angola), Florida, Peru, Hawaii, Tahiti, Panama, India, Sri Lanka, Thailand, Malay Peninsula and Philippines.

Southern part of Tanzania including Mtwara, Lindi and Ruvuma (Tunduru District) regions are the major growing cashew area and currently contribute about 80% of cashew produced annually. Cashew nuts are also important to the national economy, providing 15% of Tanzania’s foreign exchange earnings. Also cashews are often the main source of cash income for farmers.

The cashew trees tolerance to drought conditions provides a hedge against crop failure. Its' ability to grow on poor soils and to be inter-cropped with food crops makes it an ideal product for small farmers. Production responds to fertilization, but the cashew tree produces some nuts even without the application of purchased inputs. Cashew nuts are consumed as food as well as marketed for export.

In 1980's the industry almost collapsed due to several factors like shifting in agriculture from cash crops to food crops, nationalization of cashew nut processing factories also the mass relocation of people during that time that was accompanied by establishment of Ujamaa Villages program. Annual production had dropped as low as 20,000 tonnes in 1986. Currently, the country ranks as the eighth largest producer of cashew in the world and is the fourth largest grower in the continent with an average of 300,000 hectares cultivated (2% of the total area) producing more than 100,000 tonnes of cashew per year.

The cashew trees absorb nutrients from the soil and these nutrients are not replaced thus lead to loss of nutrients in the soil. The farmer's burn all leaf litter that fall under the tree when the time s close to harvesting also the cashew leaves take long time to decompose about more than two years. Cashew can be grown either as a monocrop or inter-crops with crops such as cassava, sesame, sunflower and maize when these crops are harvested their residues help replenish in the soil the macro and micro nutrients. The farming system such as application of mineral fertilizer, organic manure, limes and legumes that manage the soil fertility are not applied. The soil fertility can differ from one site to another thus the field-specific fertilizer recommendation is important.

1.2 **Statement of Research Problem**

Growing of cashew and other crops leads to nutrients loss especially Growth promoters nutrients such as N, P and K. The nutrient removal without replenishment results in a decline in soil fertility. The cropping system which includes the application of inorganic fertilizer, organic manure, lime, legume and others that tends to maintain soil fertility are not commonly practised. Matured cashew tree as perennial crop has three phenological phases which include dormancy, vegetative and reproductive phases, thus each phase may have different nutrients requirements but not known and also the soil status vary from fieled to field thus site specific fertilizer recommendation and its application technique is essential. The soil status in South-Eastern Tanzania especially at Naliendele Tandahimba and Nachingwea are not known.

Therefore appropriate strategies to manage nutrient requirements by cashew crop under different cashew farming system and soil analysis are required. This can be achieved through developing a nutrient management tool. Thus the aim of this project was to develop site- specific nutrient management tool for cashew farming systems in Tanzania.

1.3 Objectives

1.3.1 Main objective

The main objective was to develop a site specific nutrients management tool for cashew farming system in South-Eastern Tanzania.

1.3.2 Specific objectives

The specific objectives were to:

i. Determine the physical soil characteristics
ii. Determine the amount of macro and micro nutrients available in the soil such as N, P, K, Ca, Mg and Na at a specific site, together with soil reaction (PH) EC and organic matter.
iii. Design a site specific nutrient management tool for cashew farming systems in South-Eastern Tanzania
iv. Test the tool designed in (iii) above.

1.4 Significance of the study

This study is very important because at the end, the soil status of nutrients can be determined and and compared to amount required for maximum cashewnut yield. Furthermore, the nutrient management tool developed will help farmers;

i. To establish the soil nutrients status intimately at low cost compared to the laboratory analysis.
ii. To optimize the macronutrients required for cashew farming, using the tool.
iii. To identify the nutrient deficiency at any time without waiting for plant and nutrient deficient symptoms.

iv. To recommend on the type of fertilizer to be applied and amount to be applied and at what rate.
v. To improve productivity, reduce nitrous oxide emission, soil degradation and hence high yield.
vi. Finally it will increase the farmer's income, government revenues and increase competition in cashew nut productions.

1.5 **Scope of the study**

The samples was taken from three sites which are Naliendele and Tandahimba both in Mtwara district and Nachingwea in Lindi district. Due to resource limitations, only samples from Naliendele site were analyzed to determine the amount of organic carbon, pH EC, soil texture, C.E.C, Total Nitrogen and Exchangeable bases (Na, K, C, Mg).

2.0 LITERATURE REVIEW

2.1 Introduction

Cashew (*Anacardium occindentale* L.) is an important tropical perennial tree crop, originally grown in coastal areas, but now extending also far inland. It is a major export crop in terms of foreign exchange earning in countries like Brazil, Vietnam, India, Nigeria, Tanzania, Indonesia, Guinea-Bissau, Cote DIvoire, Mozambique and Benin.

Cashew nuts are common appetizers, like peanuts and pistachio nuts. They are also used in the food industry, and as an ingredient in various confectionery products. The cashew nut kernels have good nutritional value to human being. They are a rich source of vitamins (A, D and E), fat (47%), carbohydrate (22%) and protein (21%). Besides, they contain relatively important amounts of minerals like Calcium (504.0 mg/kg), Iron (90.8 mg/kg), Zinc (31.3 mg/kg), Copper (16.4 mg/kg), potassium (5600 mg/kg), phosphorus (4600 mg/kg), magnesium (2400 mg/kg) and sodium(22.8mg/kg) all measured in dry weight. However, the nutrient composition in cashew nut kernels varies with cultivar and environment. Due to its high nutritional value, even small and broken pieces of cashew nut kernels find a market in confectionery products.

Almost all varieties of *A.occidentale* produce sweet juicy apple, with high soluble sugar (fructose and sucrose) content, which are consumed as fresh fruits; or used to make various apples product such as juice and wine.

2.2 Cashew nut tree

It is an evergreen tree. There are two types of cashew cultivars classified as *A. occindentale* species:the common or giant type and the less common dwarf type. Common types grow to height ranging from 5 to 15 m, with a crown diameter of 12 to 14 m. Dwarf cashew on the other hand grows to an average height of up to 4 m high, with crown diameter of 6 to 8 m wide. Other features that differentiate dwarf from common cashew refer to a smaller stem or trunk diameter and a prolonged seasonal period of frutification. The selected cashew varieties for commercial production are AC4 and AZA2, which have high yield, desirable nut and apple qualities, tolerates major diseases and insect pests, and are adapted to wide range of agro-ecological conditions.

2.3 Ecological requirements

The cashew is a hardy and drought-resistant crop, but it is damaged by frost. It thrives under a variety of climatic and soil conditions and these conditions have an important impact on tree growth and yield (Kapinga & Kasuga , 2011)

- Altitude

  Cashew is regarded as essentially a coastal tree, though in reality it can be grown up to 1250-1300 m altitude. The reason why it is often found along sandy coasts is because it was once planted to stop erosion at sandy beaches. In addition, cashew is well adapted in low altitude, and yields are highest in such areas. For this reason the cashew is commonly grown in low altitude. Above 1000 m altitude flowering may be interfered by low temperature resulting into reduced yields.

- Rainfall

  Cashew is sometimes referred to as a rainforest species; however, the cashew trees that grow in tropical wet forests produce few nuts. Heavy rainfall, evenly distributed throughout the year, is not favourable though the tree may grow and sometimes set fruits. Coincidence of excessive rainfall and high relative humidity with flowering may result in flower abortion or fruit drop and incidence of fungal diseases such as *Anthracnose* and *Cashew Leaf and Nut Blight* (CLNB). During harvesting while nuts are on the ground, leads the nuts to rot or start germinating and also leads to the leaching of nutrients in the soil.

  Cashew requires a seasonal climate because nut production is much greater in area with a distinct wet and dry season. For good vegetative growth, flowering and fruit setting, cashew prefer a climate with an average rainfall ranging from 800-1600 mm annually (Dondeyne, 2015) and pronounced dry season of at least 4 month during which trees will flower and bear fruit. The crop can, however, withstand extremes of 500-4000 mm.

- Temperature

  Cashew is a sun loving tree and does not tolerate excess shade. It can tolerate temperatures of more than 36℃ for short period, but the most favourable temperature lies between 24-28 ℃. High temperature 39-42 ℃ during fruit set and development stage cause fruit drop and also leads to the volatilization of nutrients like nitrogen from the soil

- Soil

  Cashew grows in almost all types of soils from sandy to laterite soil, including low fertility areas which are generally unsuitable for other fruit trees. Cashew trees are often found growing wild on drier sandy soil (Taylor, 2004) or along sandy coastal areas. The tree has an extensive root system, which helps it to tolerate a wide range of moisture levels and soil types. However for optimal production it is advisable to grow it in deep, well drained, sandy loam or red soils and light coastal sands, with optimum soil pH 4.5-6.5; the minimum soil pH that Cashew can be tolerated is 3.8.

  Soils deeper than 2 m are recommended for cashew nut production. Heavy clay soils or limestone soil, or land with poor drainage condition are unsuitable for the crop. Heavy soils prevents root from penetrating downwards and sideways, thus leading to stunted growth and less drought tolerance. Shallow soils, flooded plains, valleys and swampy areas are therefore not recommended for cashew production.

2.4 Soil texture

Soil texture (or particle size distribution) is a stable soil characteristic that influences the physical and chemical properties of the soil. The sizes of the soil particles have a direct relationship with the surface area of the particles. Soil particles remain aggregated owing to various types of binding forces and factors. These include the content of OM, other colloidal substances present in the soil, oxides of Iron (Fe) and Aluminum (Al), and the hydration of clay particles.The mineral components of soil, sand, silt and clay, determine a soil texture. Soil texture affects soil behaviour, in particular retention capacity for nutrients and water.

Soil components larger than 2.0 mm are considered as rock and gravel and can be included in textural class. The large part of Mtwara districts is characterized by having sandy soil hence suitable for growth of tubers such as cassava and cashew trees.

2.5 Cation-exchange capacity (CEC)

The ability of soil to adsorb the cation and extent it can be exchanged with root is known as Cation Exchange Capacity (CEC). The higher the CEC, the more cations it can retain. It can be expressed in terms of milli-equivalents per 100 g of soil (me/100 g) or in centimoles of positive charge per kilogram of soil (cmol/kg), which is numerically equal to me/100 g. The CEC of the soil depends on clay content and organic matter.

The Organic matter also makes a very significant contribution to cation exchange, due to its large number of charged functional groups. CEC is typically higher near the soil surface, where organic matter content is highest, and declines with depth. The CEC of organic matter is highly pH-dependent.

Soil nutrients exist as positively charged or negatively charged ions when dissolved. The nutrients which exist as cations are calcium (Ca^{2+}), Magnesium (Mg^{2+}), Ammonium (Nh_4^+), Potassium (K+), Hydrogen (H+), Sodium (Na+) Aluminum (Al^{3+}), Iron (Fe^{2+}), Manganese (Mn+), Zinc(Zn^{2+}) and Copper (Cu^{2+}). Some of the nutrients which exist as anions are Chloride (Cl^-), Nitrate (No_3^-), Sulphate ($So4^-$) Phosphate (H2Po4- and Hpo4–), Borate (BO3-), and Molybdate (MoO4–).

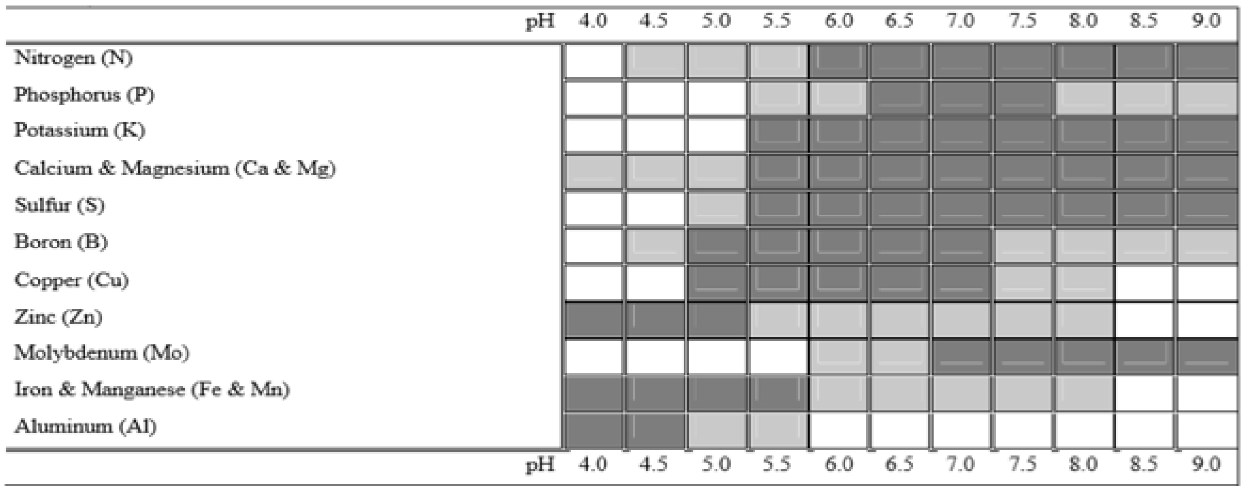
Factors influencing Cation exchange capacity

- pH
- Organic matter
- Type of soil (clay content

2.6 pH

The soil pH is the negative logarithm of the active hydrogen ion (H+) concentration in the soil solution. It is the measure of soil acidity or neutrality. It is measured by using pH meter. Furthermore, pH is a simple but very important estimation for soils as soil pH has a considerable influence on the availability of nutrients to crops. It also affects microbial population in soils. Most nutrient elements are available in the pH range of 5.5–6.5. For optimal production of cashew, it is advisable to grow it in deep, well drained, sandy loam or red soils and light coastal sands, with optimum soil pH of 4.5-6.5; the minimum soil pH that can be tolerated is 3.8.

Table 1: Soil pH effects on soil nutrients availability (Brandy and Weil, 1999)



2.7 Organic matter/carbon

Organic matter is stable in the soil. It has been decomposed until it is resistant to further decomposition. That rate increases if temperature, oxygen, and moisture conditions become favourable for decomposition. It is the stable organic matter that is analyzed in the soil test.

There are various methods for estimating organic matter in soil. Loss of weight on ignition can be used as a direct measure of the organic matter contained in the soil. It can also be expressed as the content of organic C in the soil. It is generally assumed that, on average, organic matter contains about **58%** organic C. Organic matter / organic C can also be estimated by volumetric and colorimetric methods. However, the use of Potassium dichromate ($K_2Cr_2O_7$) involved in these estimations is considered a limitation because of its hazardous nature. Soil organic matter (SOM) content can be used as an index of Nitrogen availability (potential of a soil to supply Nitrogen to plants) because the Nitrogen content in SOM is relatively constant.

Importance of organic matters to the soil

- Water holding capacity
- Soil Structure Aggregation
- Erosion Prevention

Maintaining or Improving Soil Organic Matter Levels

- Cover Crops (mulching)
- Soil-Test and Fertilize Properly

- Reduce Erosion also reduce or eliminate tillage

2.8 Care and management of cashew tree

Cashew trees need high care and management in order to produce high quality nuts and high yield; the following are the good agricultural practices;

- Weeding
- Planting in a hole with manure
- Spacing
- Pruning
- Irrigation
- Thinning overcrowded farms
- Intercropping with food crops especially nitrogen taking legumes
- Rehabilitation and upgrading farm (top working)
- Diseases control (pests and fungal pothegens)
- Fertilizer application preferably organic fertilizers
- Post-harvest handling

2.9 Fertilization

In order to get better yield, it is essential to maintain adequate N: P: K ratio in the soil. Application of 10-15 kg of farmyard manure per plant is recommended to ensure adequate organic matter in the soil.

The fertilizers recommended for a mature cashew tree are 500 g N (1.1 kg Urea), 125 g P_2O_5 (750 g Single Super Phosphate and 125 g K_2O (200g muriate of potash) (Vitor et al, 2006). The ideal time for application of fertilizer is immediately after the cessation of heavy rains. Fertilizers should be applied in a circular trench along the drip line. Before application of fertilizer it should be ensured that there is adequate soil moisture.

The fertilizers should be applied in two split doses during pre-monsoon (May – June) and post monsoon (September – October) season. However, in the case of single application, it should be done during post monsoon season (September – October) when adequate soil moisture is available.

In sandy and laterite soils, soils of sloppy land and in heavy rainfall zones, the fertilizer application should be done in a circular trench of 25 cm width and 15 cm depth at 1.5 m from the tree trunk. In red loamy soils and in low rainfall areas, the fertilizers should be applied in circular bands at a distance of 0.5 m, 0.7 m, 1.0 m and 1.5 m away from the trunk during first, second, third and fourth year onwards of planting, respectively.

2.10 Nutrients managements for cashew farming

Essential nutrients required for the growth and maximum yield of cashew are N, P and K other nutrient such as Zn, Mg, Fe and other. Manure and fertilizer promote the growth of the plants and promote the onset of flowering in young trees by supplying adequate nutrients.

Organic manure is found essential during the early stage preferable during the planting in the pits. It increases 2-3 times of yield compared to non-manure plants. Fertilizers are applied regularly to ensure high yield from mature trees. The amount of fertilizer applied depends, on the age of the cashew trees, among others.

Yield is affected when plants nutrients are deficient and when the deficiency is corrected yield increases rapidly until the critical range of plants nutrients concentration achieved and yield is maximized. Elements absorbed in excessive quantities can reduce the plant yield directly through toxicity or indirectly by reducing the concentration of other nutrients below their critical range. The minimum amount of fertilizer required to maximize the crop yields is called optimum physical rate or agronomic optimum rate. Adequate nutrients supply from the soil or applied nutrients are vital for the soil fertility and crops production. A limitation of one essential element nutrient can affect the growth and crop yields.

The following are the roles of nutrients to the cashew tree;

1. **Nitrogen(N)**

   Total N includes all forms of inorganic N, such as NH_4, NO_3 and NH_2 (urea), and the organic N compounds such as proteins, amino acids and other derivatives. While nitrogen can be taken in and converted into a usable nutrient from the atmosphere, and may be naturally present in soils, it is almost always desirable to supplement nitrogen to ensure plants have the optimum amount available to them.

   The materials that can be included in NPK blends as a source of nitrogen are Urea, Urea Ammonium, Nitrate Anhydrous Ammonia and Manure.

Roles of Nitrogen in cashew tree

- Necessary for formation of amino acids, the building blocks of protein
- Essential for plant cell division, vital for plant growth
- Directly involved in photosynthesis
- Necessary component of vitamins
- Aids in production and use of carbohydrates
- Affects energy reactions in the plant

Nitrogen deficiency symptoms

Light sand soil of the coast region where the cashew trees grown lack organic matter and poor nitrogen contents.

- At low nitrogen contents cashew seedling (2 years old) is characterized with a general yellowing of the older leaves that soon spread to the young once. The colour of the leaves changed gradually from dark green to pale green and then yellow colour
- The leaves are small
- Stem thin and elongated
- Stem turn reddish, yellowing, or chlorosis appear first in leaves
- Lack of nitrogen in cashew seedling become visible after seven (7) weeks after planting.

Remedial measures by application of nitrogenous fertilizer

2. **Phosphorus(P)**
    - Involved in photosynthesis, respiration, energy storage and transfer, cell division, and enlargement
    - Promotes early root formation and growth
    - Improves quality of fruits, vegetables, and grains
    - Vital to seed formation
    - Help plants survive harsh winter conditions
    - Increases water-use efficiency
    - Hastens maturity

Phosphorus deficiency symptoms

- Stunted growth of plants with dull-green foliage and by the fifty month lower leaves of cashew seedling wither and fall
- Mostly severe deficiency occurs in dark green, leathery texture and reddish purple leaf and margins.

Remedial measures is application of phosphate fertilizers during the planting in pits or localized in roots region

3. **Potassium (K)**

- Carbohydrate metabolism and the breakdown and translocation of starches
- Increases photosynthesis
- Increases water-use efficiency
- Essential to protein synthesis
- Important in fruit formation
- Activates enzymes and controls their reaction rates

Potassium deficiency symptoms

- Potassium deficiency symptoms may develop in cashew seedling within a month or two after planting.
- Lack of Potassium causes stunted plants with small branches and little vigor
- K deficient plants exhibit chlorosis or yellowing along the leaf margins or tip starting with the bottom leaves and progressing up the plant.
- Leaves appear dry and scorched at the edges and the surfaces are irregular chlorotic.

Remedial measures is application of potassium fertilizer the cashew trees it response to potassium only up to 150g per tree per year

4. **Magnesium**

- It is constituents of chlorophyll molecules
- Closely associated with the energy supplying Phosphorus compounds
- It is essential for the formation of seed with high oil content

5. **Calcium**

- Calcium is concerned in the activities of growing points and proper roots developments

Micronutrients

For the estimation of micronutrients in soils, it is the plant-available form that is critical and not the total content. The major objective of soil testing for micronutrients, as with macronutrients, is to determine whether a soil can supply adequate micronutrients for optimal crop production or whether nutrient deficiencies are expected in crops grown on such soils. The most commonly studied micronutrients are Zn, Cu, Fe, Mn, B and Mo. These plant food elements are used in very small amounts, but they are just as important to plant development and profitable crop production as the major nutrients. Especially, they work "behind the scene" as activators of many plant functions.

2.11 Atomic Absorption Spectrometer (AAS)

Spectrophotometry is a tool that hinges on the quantitative analysis of molecules depending on how much light is absorbed by coloured compounds. Spectrophotometry uses photometers, known as spectrophotometers that can measure a light beam's intensity as a function of its color (wavelength).

The absorption of light is due to the interaction of light with the electronic and vibrational modes of molecules. Each type of molecule has an individual set of energy levels associated with the makeup of its chemical bonds and nuclei, and thus will absorb light of specific wavelengths, or energies, resulting in unique spectral properties.

It is used in various scientific fields, such as physics, materials science, chemistry, biochemistry, and molecular biology. They are widely used in many industries including semiconductors, laser and optical manufacturing, printing and forensic examination, and as well in laboratories for the study of chemical substances.

In an analysis employing an atomic absorption spectrometer (AAS), the sample in the form of a homogeneous liquid is aspirated into a flame where “free” atoms of the element to be analysed are created. A light source (hollow cathode lamp) is used to excite the free atoms formed in the flame by the absorption of the electromagnetic radiation. The decrease in energy (absorption) is then measured. It follows the Lambert–Beer law, i.e. **the absorbency is proportional to the number of free atoms in the ground state** (Baker & Suhr, 1982)

Principle of operation of spectrophotometer

The light source is shone into a monochromator, diffracted into a rainbow, and split into two beams. It is then scanned into a sample and reference solution Fractions of the incident wavelengths are transmitted through, or reflected from, the sample and the reference. The resulting light strikes the photo detector device which compares the intensity of the beam. Electronic circuits convert the relative currents into linear transmission percentages and/or absorbance/concentration values.

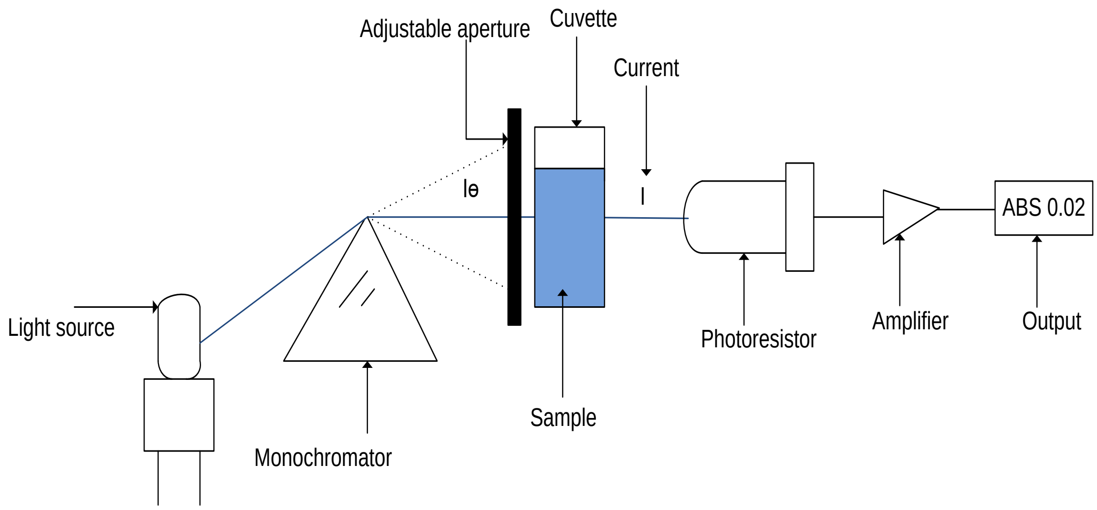


Figure 1: Flow diagram showing principles of operation of spectrophotometer

2.12 Site Specific Software Management Tool

Is an interactive, computer based decision-support tool that will enable farmers to rapidly implement nutrient management in their individual fields with or without soils testing. The software will estimate the attainable yield for a farmer's field based on the growing conditions (water management, soil characteristics, cashew tree varieties), determines the nutrient balance in the cropping system based on yield and fertilizer/manure applied in the previous crop and combines such information with expected Nitrogen (N), Phosphorus (P) and Potassium (K) response in target fields to generate location-specific nutrient recommendations. The software also does a simple profit analysis comparing costs and benefits between farmers' current practice and recommended alternative practices.

The software tool can also be integrated with a hardware device that will be used to collect information that is usually collected by extension workers, crop advisors and service advisors and upload it to the computer software on the computer where analysis, visualization and recommendation of nutrients will take place.

2.13 Recent studies on Nutrients Management on Cashew Farming

Table 2: Recent studies on Nutrients Management on Cashew Farming

S/N	REFERENCES	WHAT WAS STUDIED	RESULTS
1	(Gajbhiye R. C, Salvi S. P, Pawar S. N, 2016)	Impact of organic manure on the plant growth and yield of cashew. <u>Method</u> The some eight old month cashew (V-4) were planted 7m×7m in 2008. Their experiment conducted from 2011-2012 to 2014-2015 had eight treatment and three replication that were (T_1-100 % N as FYM, T_1 + bio fertilizers consortium (BCF) (200g/tree), T_3-50% N as FYM + BCF (200g/tree) + rock phosphate, T_4- 100% N as vermicompost + BCF (200g/tree), T_5- recycling of organic residue with the addition of 20 per cent cow dung slurry (20% weight of organic residue as cow dung slurry), T_6- *In situ* green manuring/green leaf manuring to meet 100% (retain litter + planting	Their finding show that on various organic manure application of 50% N as FYM + BCF (200g/tree) + rock phosphate (T_3) recorded maximum number of panicles/m2 (17.53/m2) followed by T_8 – control. Recommended dose of fertilizer + 10 kg FYM (16.58/m2) and T_6 - *In situ* green manuring/green leaf manuring to meet 100% (retain litter + plantin cowpea) (16.32/m2). Using of recommended dose of fertilizer + 10 kg FYM (T_8-control) had significantly the maximum mean pooled yield of 4.8 kg/tree and it was dominant than the other treatment.

		cowpea) T_7- 25% N as FYM + recycling of organic residues + *Insitu* green manuring/green leaf manuring + BCF (200g/tree) and T_8- control- recommended dose of fertilizer + 10 kg FYM).	
2	(Edibo G et al, 2010)	Fertilizers application recommendation on cashew tree <u>Method</u> Soil sample, leaves sample and nut were collected from different farmers analysed in the laboratory to determine the available nutrients.	- Amount of Ca in the soil it differ range between the 0.817-0.960cmol/kg but its average value is 0.868cmol/kg. The amount of Ca in all farms was above the critical value 0.8ccmol/kg in the soil. - The quantity of the Mg it range between 0.004cmol/kg-0.01cmol/kg and its average value 0.007cmol/kg. The amounts of Mg were below the critical value required for farming which is 0.08cmol/kg in soil - The Na content in the soil varies in 0.12cmol/kg-0.26cmol/kg their mean value 0.17cmol/kg. - The three farm out of ten farms selected for the experiments their amounts of K were below the

			critical value for cashew farming which is 0.12cmol/kg - The content of P it differ from 2.00ppm-7.27ppm and their average was 4.07ppm. The results indicated that only three out of ten had adequate phosphorus cashew farming - The pH range from 5.10-5.85 with the average value 5.49. All farms had pH range within the adequate pH for cashew farming reported that cashew grow in soil with pH range from 3.5-6.5 but it grow well in pH range from 4.5-6.5 - The total nitrogen amounts in the soil it varies from 0.02%-0.11% and their mean value was 0.04%. The value is below the critical value required for cashew cultivation which is 0.1%. - Soil organic matter range from 0.40%-1.3% with the mean value 0.69%.
3	(Adejumo et al, 2010)	Effect of application of NPK fertilizer on the cashew yield and inflorescence blight cashew	- The application of single super phosphate at 144kg/h significance reduce disease

		resistance <u>Working condition</u> Three treatments of urea for nitrogen (0, 60 and 120 kg/ha), murate of potash for source of K (0, 24 and 48 kg/ha) and single super phosphate (0, 72 and 144 kg/ha) for the source of potassium in 2000 to 2001were used.	infection and increase the yield in the next year. -Application of both urea at 120kg/h and MOP at 48kg/h provide high yield 3.53kg/tree and minimize the disease infection for the first year and the application. - When NPK applied at urea at 60 kg/ha, SSP at 144 Kg/ha and MOP at 24 kg/ha provide the highest yield for the second year and significantly reduced the disease infection s(125 inflorescence panicles infected)
4	(Noel, 2001)	Effect of application of K, P and S on the yield of cashew and effect on the soil when over use	-Application of P up to 288g/tree/year and 178g/tree/year significance increase the yield five times of cashew nut in the world market and the cashew nut weight was greater than 0.91g/kernel -Application of K up to 3000g/tree/year did not increase the yield - When the trees become mature optimum rate of P and K for the high yield increased each year from 90g/tree/year up to

			150g/tree/year for the P and for S increased from 35g/tree/year to 50g/tree/year -The surface area the pH, increase 1.4 unit because application of dolomite as source of Ca and Mg - At depth below 100cm the soil pH decrease 1.2 units -Irrigation increase the exchangeable Na about 0.15cmol (+)/kg and exchangeable k increased about 0.57cmol (+)/kg. - The exchangeable Ca, Ma, Zn Cu and Mn did not increased at depth but their level were high at top soil (0-30cm) suggesting that fertilizer that containing the residue were accumulated at the top layer. Also P accumulated at the surface horizon from 0-15cm increased from 3mg/kg in 1996 to 33mg/kg in 1998.

From the literature above, the reviews helps to recommends on the application of fertilizer on the soil and some was adopted during soil analysis. The method of soil analysis, fertilizer application and the designing of tool can be adopted and then improved to attain better results. This helps in comparison of the results with optimum value of both macro and micro nutrients in the soil for better yield of cashew though soil status differ from filed to field but can gives a real picture during discussion of the results.

3.0 METHODOLOGY

3.1 Site survey

Site survey is an inspection of a study area where work is proposed to take place. This was done at three sites which are Naliendele, Nanyanga and Nachingwea. Mostly we based on the specific site in polyclonal seed garden (PSG) in each site though we surveyed in the whole cashew farms around NARI. This helped to get a real feelings on evaluation of the project, in collecting data and prioritize the actions based on objective data rather than relying on subjective “gut” feelings, and also helped to gather objective information to make sound data-driven decisions.

3.2 Soil and leaves sampling

This involved taking and scoring soil and leaves respectively; the samples were taken at three specific sites: Naliendele (Mtwara region), Nanyanga (Mtwara region) and Nachingwea (Lindi region). Both soil and leaves were taken from four blocks from within an area of 1.5 acres each in PSG based on two varieties of cashew AC4 and AZA2.

The sample was taken from 3 trees around the canopy of each variety per block, and soil of depth 0-20 cm and 20-50 cm as well as 2 m for general soil profile. The sample was taken in four different place 3 m from the truck around the tree (in N, S, E and W direction) and then mixed to obtain a representative sample. Then a representative soil sample was taken based on depth (0-20cm and 20-50 cm) while leaves were collected representative of young and matured leaves. About 2 kg of soil per sample were taken. In total soil samples per site were 48 and for assessment of soil profile 5 samples of soils were collected per site (Ap, BA, Bw1, Bw2 and Bw3). A total of 48 samples of leaves per site were collected for analysis in the laboratory.

Figure 2: Physical Soil Analysis in Nachingwea farms

3.3 Experimentation

3.3.1 Aim

To determine the amount of macro and micro nutrients (N, P K, Ca, Na, and Mg), CEC, pH, EC, Organic matters/carbon and soil texture class available in the soil samples.

3.3.2 Experimental Location

The experiment was conducted in Botany Laboratory at Botany department, University of Dar es Salaam.

3.3.3 Apparatus and equipment

- Masking tape
- Maker pens
- Spatula (stainless)
- Sieves (2mm)
- Mortar and pestle
- Pencils
- Oven
- Muffle furnace
- pH meter
- Electro conductivity meter
- Atomic absorption Spectrophotometer (AAS)
- Spectrophotometer
- Beakers
- Plastic beaker
- Pipette
- Volumetric Flask
- Filter papers
- Tissue paper
- Gloves
- Analytical balance
- Porcelain Crucible

- Stirring rod
- Ruler
- Desiccators
- Measuring cylinder
- Bucket
- Vacuum pump
- Test tubes
- Vacuum manifold with filter flasks, Buchner funnels, filter paper (Whatman No. 1)

The analysis was carried out according to standard procedure as described by Motsara and Roy , (2008), and Bruce and Donald ,(2009).

3.3.4 Soil preparation

The procedure followed is according to Bruce and Donald (2009)

- Grinding and sieving

  The soil was ground by using mortar and pestle and then sieved using 10 mesh sieves of 2 mm size.

- Mixing

  After sieving the soil, the soil sample was mixed thoroughly to attain homogeneity.

3.3.5 Determination of soil texture by hand feel

Procedure

1. About 25g of air dried-sieved soil was placed in hand and water was added by drops then mixed until it form a ball,
2. The ball of soil was squeezed between thumb and finger, and a long and thin ribbon was formed,
3. The ribbon was extended by pushing it over the finger until it cracks and breaks,
4. The soil was assessed whether it formed a ribbon or not. In case a ribbon was formed, then the length of the ribbon was measured and referred to the key, that is if yes form a weak ribbon of less than 2cm, medium 2-5cm, strong more than 5cm long before breaking.
5. The soil texture was identified.

3.3.6 Determination of pH and Electro Conductivity (EC)

Procedures

1. The pH meter was calibrated over the appropriate range using the standard buffers,
2. 15 g of sieved, air-dried soil was measured and then placed into a volumetric flask
3. 30ml of distilled water was added into a flask and then shaken for 1 minute
4. The suspension was stirred and was left to stand for 5 minutes
5. Electrode of conductivity meter was placed in the slurry, swirled carefully and the conductivity readings were taken immediately (the electrode tips should be in the slurry) then
6. Electrode of a pH meter was placed in the slurry, swirled carefully and the pH readings were taken immediately.

3.3.7 Determination of organic matter (OM) and organic carbon (OC)

Procedure

1. 5 g of sieved air-dried soil sample (W_1) was weighed and placed in a Porcelain Crucible then labeled,
2. The crucibles were placed in a muffle furnace and temperature was set at 400℃ then left for about 4 hours,
3. The muffle furnace was switched off after 4 hours to allow the sample to cool to ambient temperature then the samples were weighed as (W_2)
4. Calculations.
5. The percentage of OM is given by

$$\left(\frac{W1-W2}{W1}\right)\times 100\% \text{...Equation 1}$$

Then, the percent of organic C is given by: % OM × 0.58.

Note: It is generally assumed that, on average, OM contains about 58 percent organic C

3.3.8 Determination of Phosphorus (P)

Principle

In acid solution, orthophosphate react with molybdate and antimony III antimony-12-phosphorus molybdene acid, which ascorbic acid reduces to a blue complex (molybdene blue). The color of the complex is measured at 872nm in spectrophotometer (1-5 cm) cuvette.

Chemicals

1. Ammonium molybdate, [$(NH_4)_6 Mo_7 O_{24}.4H_2O$]
2. Potassium antimony tartrate [$K(SbO)C_4H_4O_6.0.5H_2O$]
3. Ascorbic acid [$C_6H_8O_6$]
4. Sulphuric acid [H_2SO_4], conc.
5. Distilled water
6. Anhydrous potassium dihydrogen phosphate [KH_2PO_4] (100ppm P). Dissolve 0.4392g KH_2PO_4 (water free) in 1000ml (5).

Reagents

- R1: Dissolved 2.8g (3) in 200ml(5)
- R2: 100ml A + 22.5ml B + 2.5ml C + 125ml (5)
  A= Dissolved 217 ml (4) in 1000ml (5)
  B= Dissolved 64.1g (1) in 500ml (5)
  C= Dissolved 4.79g (2) in 100ml (5)
- Troug's reagent as extractant

Procedure

1. 5g of soil sample was placed in a 250-ml flask,
2. 30ml of Troug's reagent was added into the flask then shaken and left to stand overnight,
3. The mixture was decanted to obtain clear solution,
4. To 25ml of decanted solution, 2ml of both R2 and R1 were added simultaneously then shaken,
5. The solution was left to stand until the colour change to blue

6. The sample was analysed by using spectrophotometer at wavelength of 872 nm and the absorbance of the samples was determined.
7. The standard curve for phosphate (PO_4^-) was prepared. The concentration of phosphate used in preparation curve was in range of 0.1 to 1 ppm and the corresponding absorbance was taken, then a plot of absorbance against concentration (ppm) was plotted.
8. The concentration of the sample was obtained direct from the standard curve, using the correlation obtained from the curve.

3.3.9 Determination of Cation Exchange Capacity and exchangeable bases (K, Na, Mg, Ca)

Chemicals and reagents

- 1M Ammonium acetate(CH_3COONH_4) of pH 7.0, extractant solution
- 95% Ethanol
- Sodium acetate(CH_3COONa)
- Sodium hypochlorite
- Combined reagent

Procedure

1. 5g of soil sample was placed into a conical flask and 30 ml Ammonium acetate of pH 7.0 was added then shaken and left to stand for 24 hours,
2. The suspension was filtered under pressure by using vacuum manifold with filter flasks, Buchner funnels, filter paper (Whatman No. 1),
3. The filtrate was stored into a flask for analysis of exchangeable bases (K, Na, Mg, Ca) using Atomic Absorption Spectrometer (AAS),
4. 20 ml of Methanol was added to the dry soil cake (remained soil on Whatman paper for leaching of exchangeable bases) then filtered,
5. 30 ml of Sodium acetate was poured on the soil cake then filtered for Cation Exchange Capacity analysis,
6. 1ml of filtrate in (5) above was taken and 29 ml of distilled water was added then mixed and then 1ml of the solution was taken as sample solution onto a plastic tube,

7. 8 ml of combined reagent and 0.5 ml of sodium hypochlorite was added into a plastic tube respectively and left until colour changed to green,
8. The sample was analysed using spectrophotometer at wavelength of 660nm
9. The standard curve was prepared using concentration of NH_4^+, it's prepared by plotting NH_4^+ concentration on the X-axis and the spectrophotometer readings on the y-axis. An unknown sample extract was fed onto the spectrophotometer and the reading was taken corresponding to which the concentration of NH_4^+ is read from the standard curve.

3.3.10 Determination of total Nitrogen (N)

Chemical and reagents

- Copper
- Sulphuric acid (93–98 percent)
- Sodium hypochlorite
- Copper sulphate ($CuSO_4 .H_2O$)
- Potassium sulphate or anhydrous sodium sulphate
- 35-percent sodium hydroxide solution
- 0.1M HCl or 0.05M $H_2 SO_4$
- Salicylic acid
- Boric acid

Procedure

1. 0.1 g of dried-sieved soil sample was put into a beaker then copper was added as catalyst,
2. 5 ml of digester was added onto a beaker and then pieces of glass were added,
3. The beaker was placed in an hot plate in fume chamber then heated at a temperature of 400℃ until colour changed to blue,
4. The sample was cooled in a fume chamber for about 30 minutes, and then 50 ml distilled water was added to make a solution,
5. 1ml of solution made in step 4 was put into a plastic tube and 8 ml combined reagent for total nitrogen was added and then 0.5 ml of sodium hypochlorite was also added,

6. The solution was analysed by using spectrophotometer at 660nm
7. The standard curve was prepared; by using known concentrations of NH_4^+,(obsorbance taken using uv -visiblespector) it's prepared by plotting NH_4^+ concentration on the X-axis and the spectrophotometer readings on the Y-axis. An unknown sample extract was fed onto the spectrophotometer and the reading was taken corresponding to which the concentration of NH_4^+ is read from the standard curve.

4.0 RESULTS AND DISCUSSION

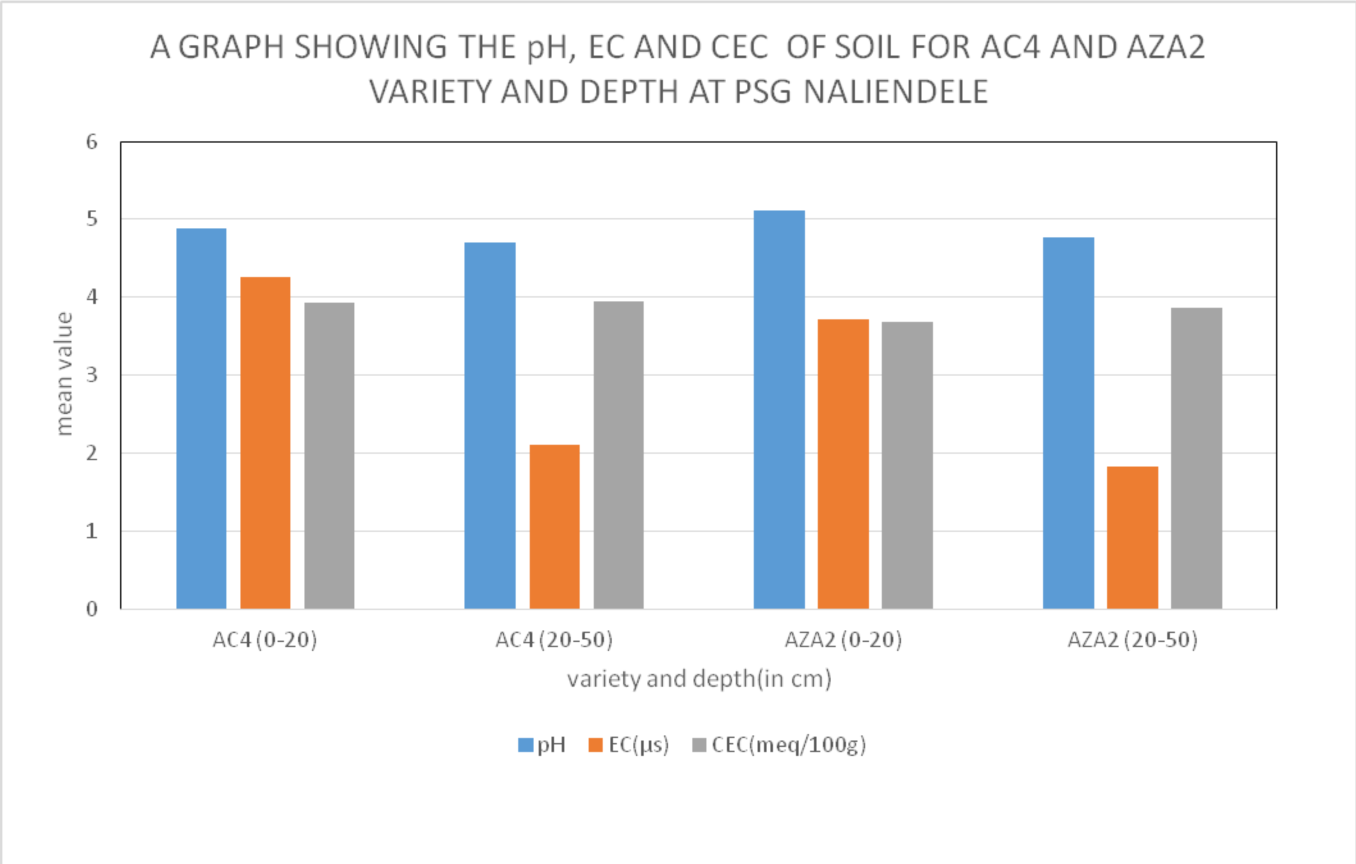


Figure 3: A graph showing the pH, EC and CEC of soil for AC4 and AZA2 variety and depth from Naliendele site.

Textural class

The soils were sandy loam for the depth of 0-20 cm and 20-50 cm for all samples (48) and also for the profile the soil was sandy loam at Ap and BA while sandy clay loam for Bw1, Bw2 and Bw3. Generally the soil at Naliendele was of sandy loam type.

Generally the soil pH is slightly acidic to acidic (5 - 4) for all site sampled AZA2 and AC4 were as there is tendency to decrease down the profile. The EC is extremely very low in all sites visited and showed to decrease down the profile suggesting that all site belongs to leached ferrallitic soil (low pH low EC). The CEC in all sites was very low and falls the limit of 24 meq /100g commonly taken as the limit for intensely weathered soil.

The analysis show that there is no significant difference in pH between the different depths ($p > 0.05$) (Figure 22). The values are in optimum range of 4.5-6.5 and minimum soil pH that can be tolerated is 3.8 (Kapinga & Kasuga, 2011) hence it's in a good range to support the availability of nutrients to both soil and plants and influence the Cation Exchange Capacity. The value of EC varied from 2.310 to 3.140 with a mean value of 2.768 and standard deviation of 0.357 which is in range of critical value 2-3 (Table 6), where the analysis show that there is no significant difference between the soil at different depth from 0-200 cm (Figure 21). The suitable CEC for cashew should be (>10cmol/kg) though the optimal value is 2.6-8.5 cmol/kg), hence the soil has low CEC this can be due to low organic matter and very low clay fractions. The low value of CEC suggests that the soil nutrient status is poor due to very low nutrients holding capacity.

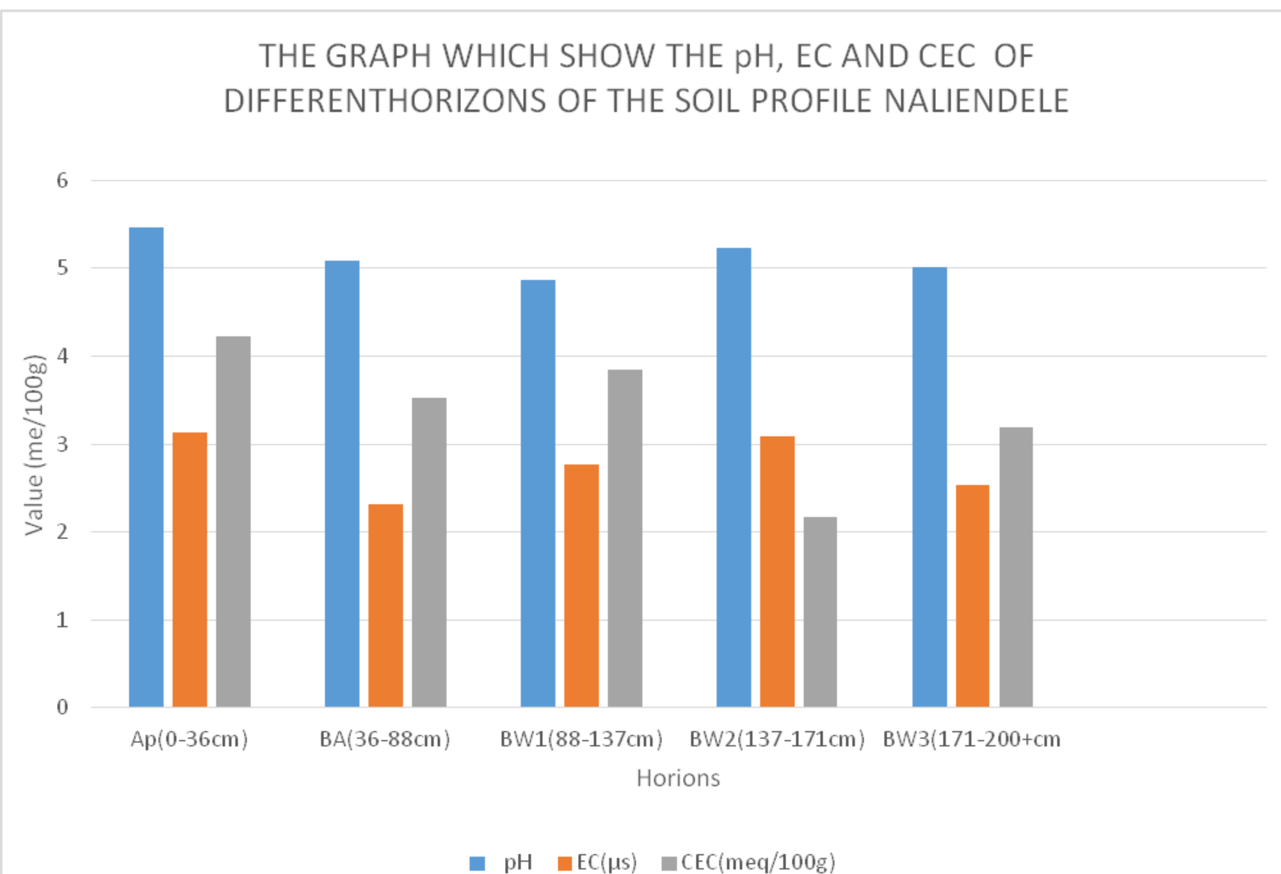


Figure 4: A graph showing the pH, EC and CEC of different horizons for the soil profile

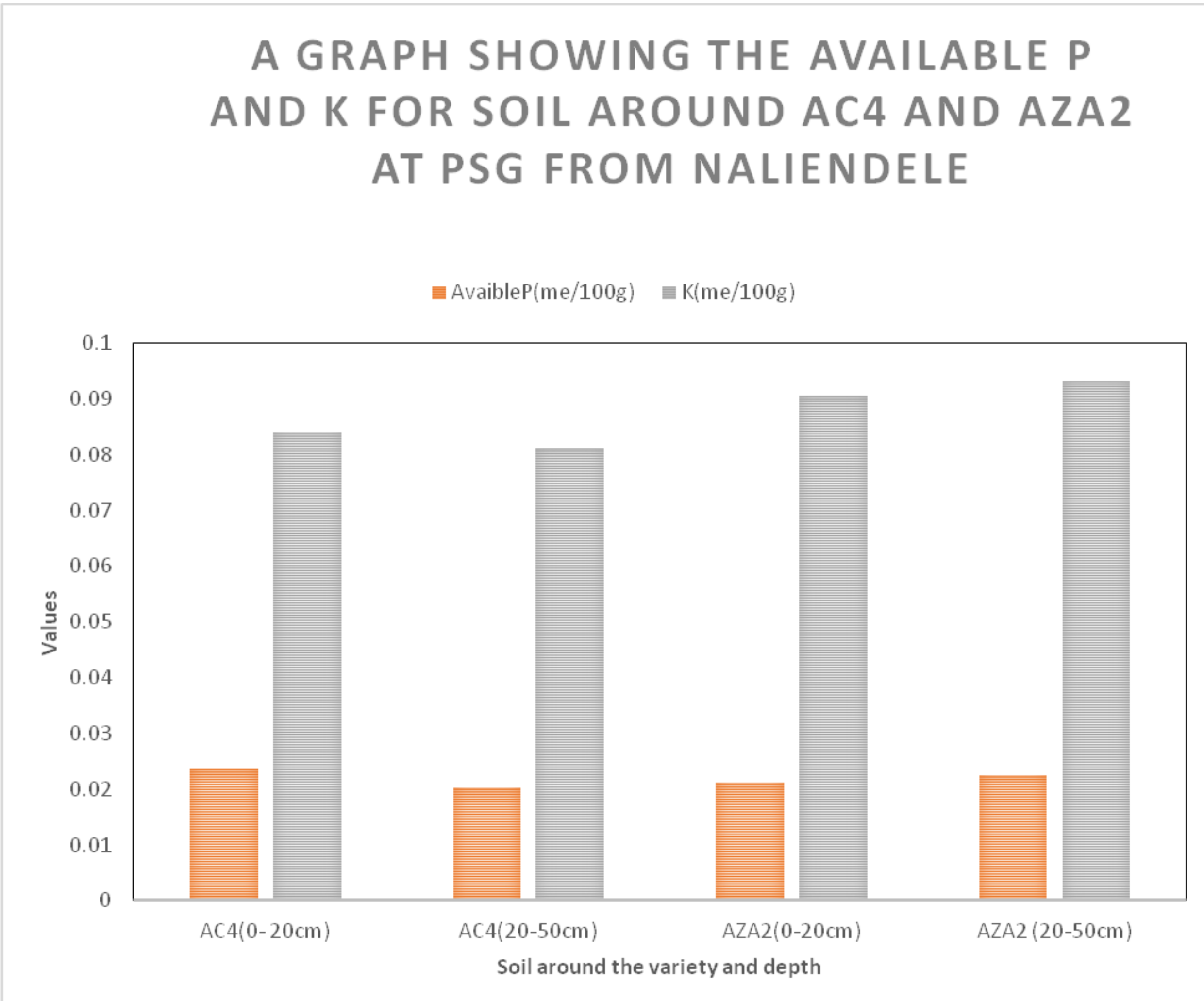


Figure 5: A graph showing the available P and K for soil around AC4 and AZA2 at PSG

The value of P is high at the top compared to the bottom while there is no significant difference between both depth and sites. The concentration of P on the top . Also the value of K is higher at the bottom compared to the top though there is no significance different between the depth and variety. The soil has low concentration of P and K compared to the critical value, this may be due to nature of leached ferrallitic soil, poor agricultural practices ie lack of organic matter additional and soil erosion which tends to decrease organic A horizon. Also the analysis shows that there is no significant difference between the samples of soil profile ($p>0.05$) (Figure 13)

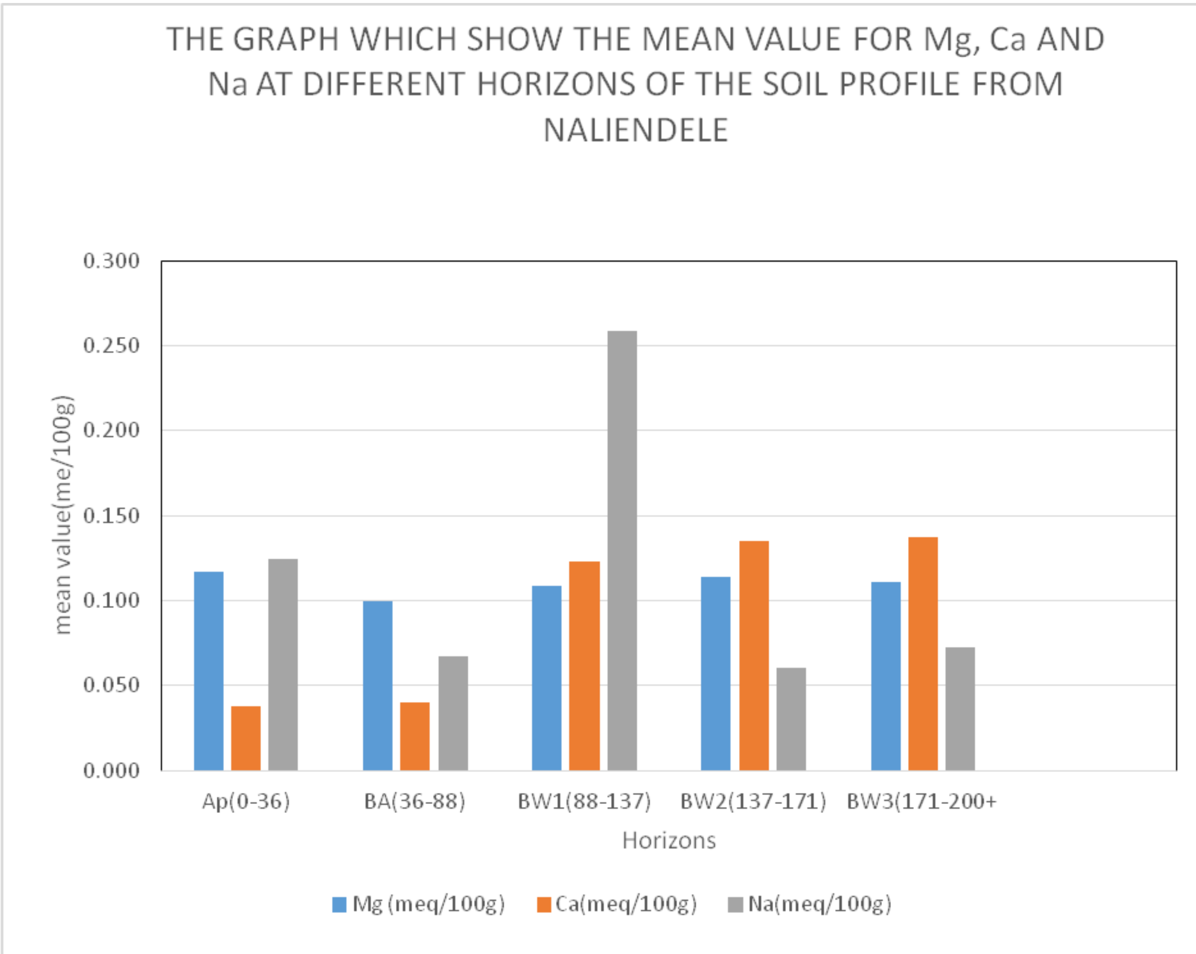


Figure 6: A graph showing Mg, Ca and Na at different horizons for the soil profile

The soils exchangeable base **Na K Ca and Mg** were above the critical value of 0.08cmol/kg soil and also were higher at the top soil compared to the subsoil. The moderately high exchangeable base at the top soil of the leached ferrallitic soil is highly attributed to mobilized minerals in cashew nut fruits after the decaying of the false fruits (commonly referred by the locals as MABIBO) and this is supported by the facts that we sampled the soil just after fruit shed

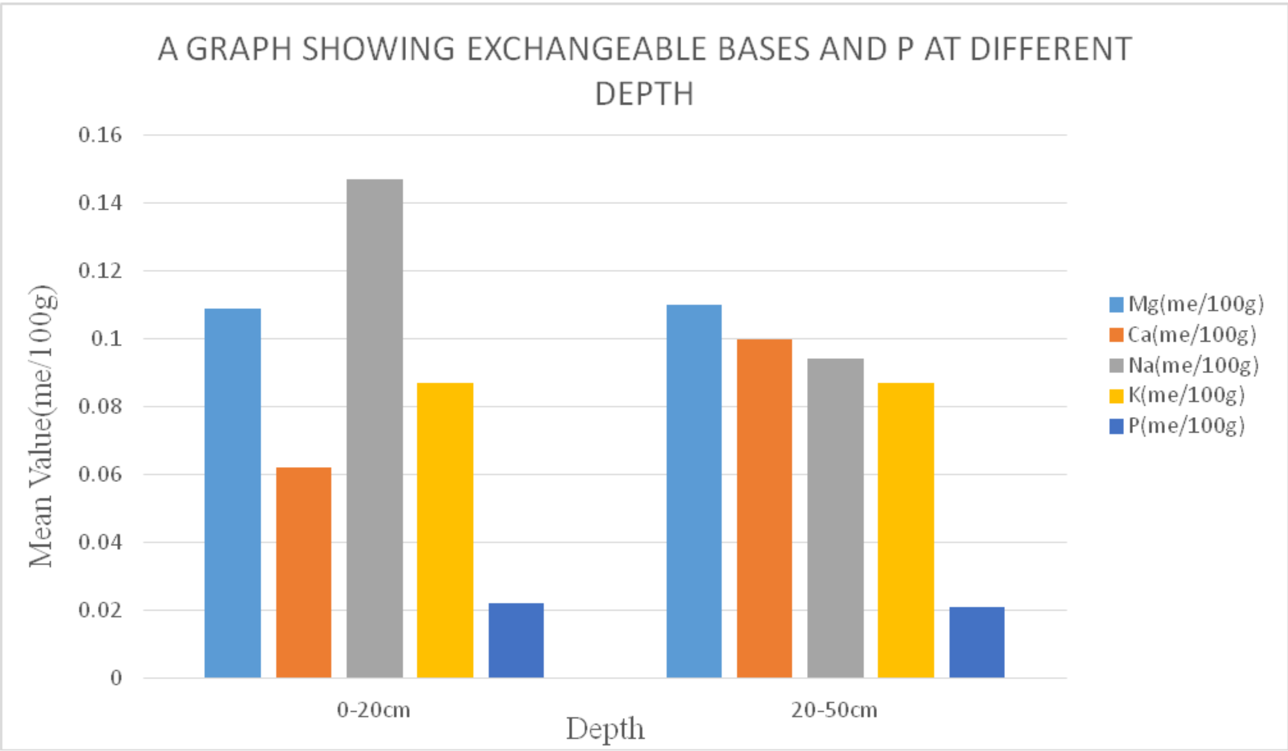


Figure 7: A graph showing Exchangeable bases and P for different depth

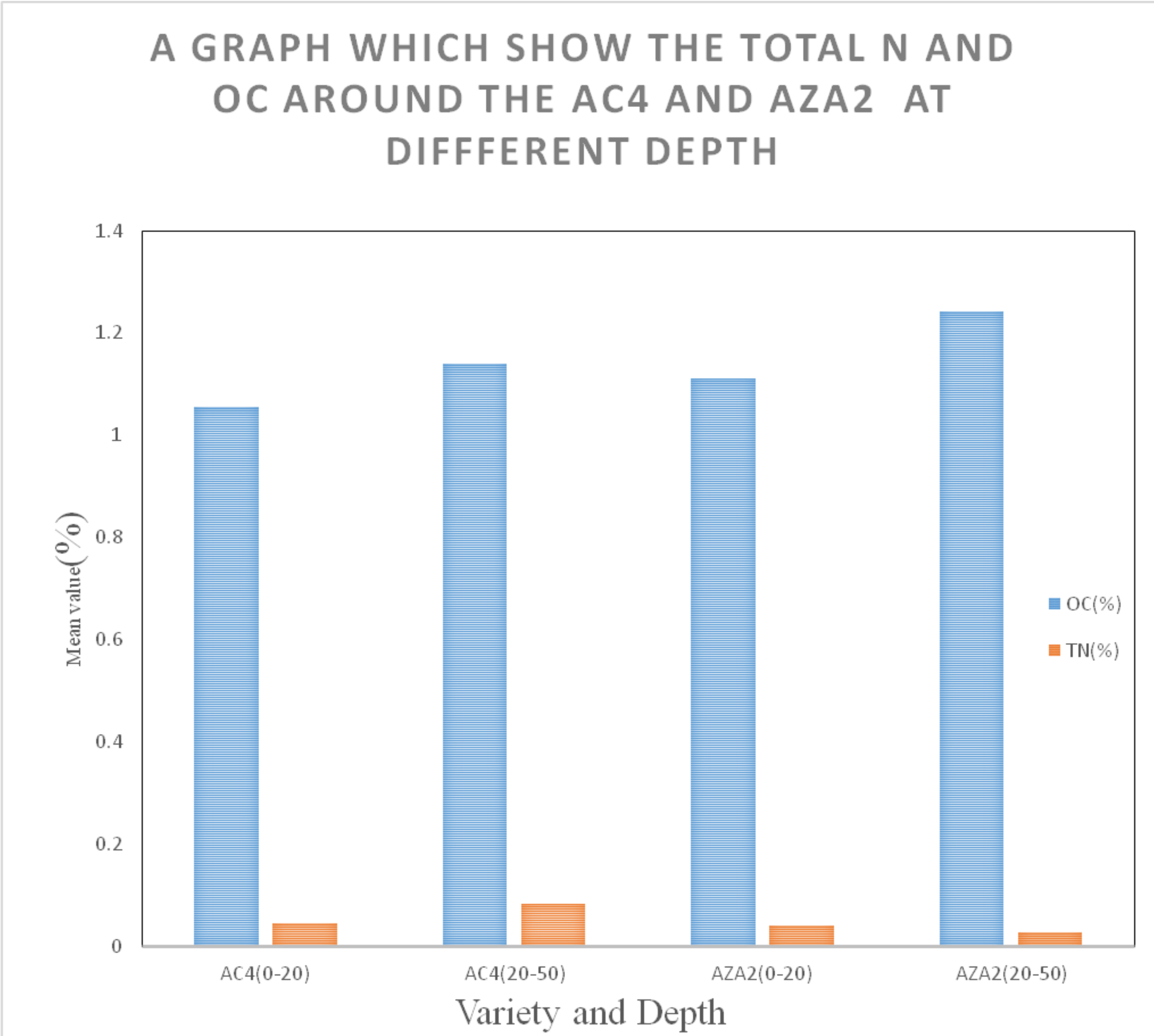


Figure 8: A graph showing total N (%) and %OC around AC4 and AZA2 at different depth

The N contents was higher at the depth of 20-50cm for AC4 while the organic carbon/matters is high at the bottom in both AC4 and AZA2 this is due to the nature of the sandy soil. Soil organic matter might have also been lost through poor agricultural practice like burning of cashew leaves and poor tillage.

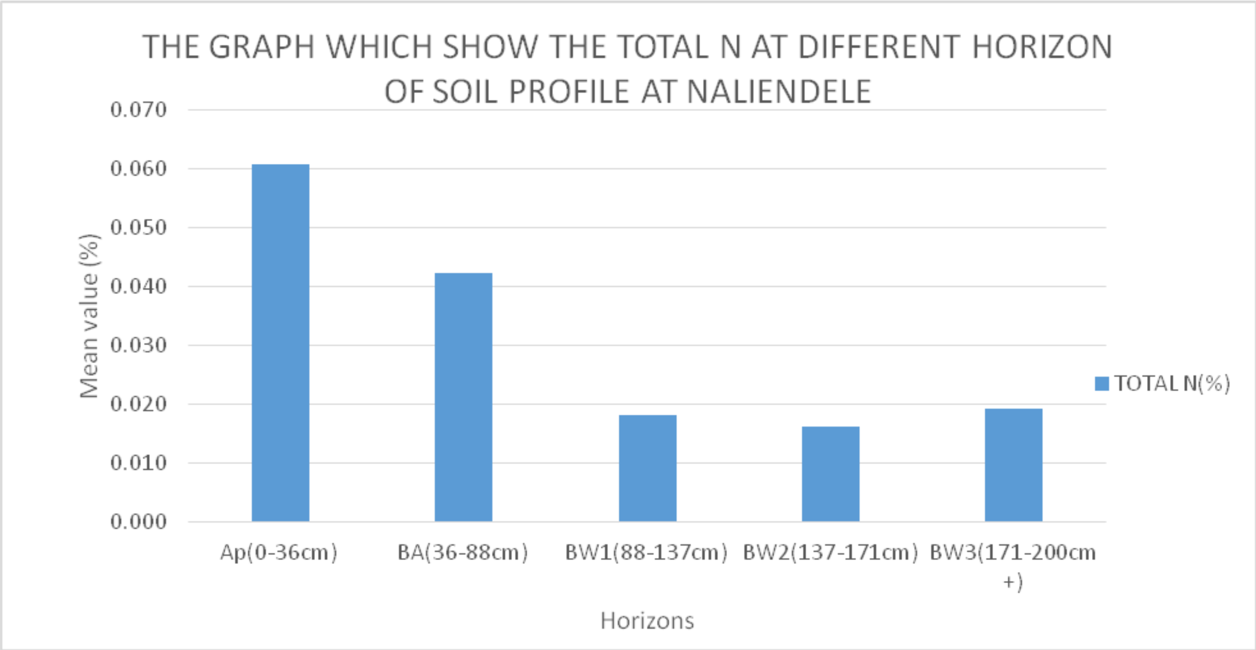


Figure 9: A graph which show the total N at different horizon of soil profile at Naliendele

The Nitrogen contents is highly concentrated at the top but statistically there is no significance difference between the samples (p> 0.107) (Figure 19). Generally, the nitrogen content is grossly below the critical level of 0.1% required for cashew cultivation (Egbe , 1989). The low N content could be due to the lack of organic matter incorporated into soil.

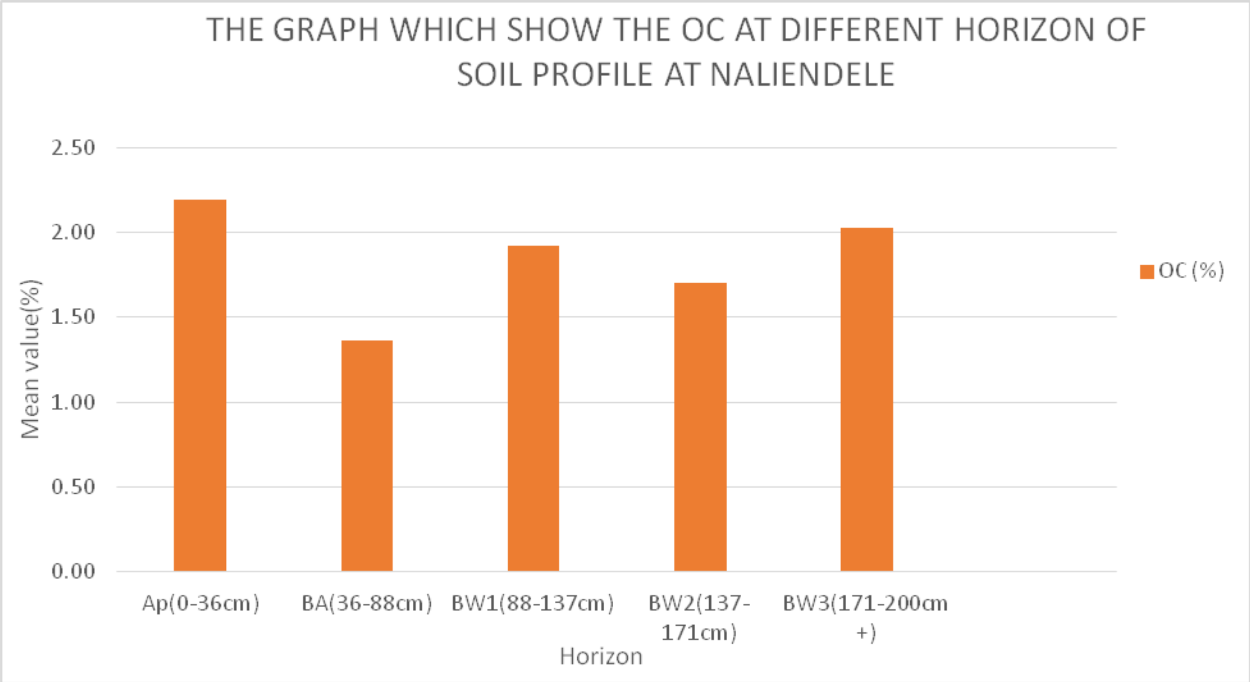


Figure 10: A graph which show the OC (%) at different horizon of soil profile at Naliendele

5.0 CONCLUSION AND RECOMMENDATIONS

NARI works hard to ensure high production of cashew nut and with high quality. Till now they have more than 54 cashew nut varieties, this proves that they are aiming at leading in cashew nut production worldwide. The soil status is among of the factor to consider in the establishment of cashews farms but is not yet done at NARI.

Most soils in the cashew growing areas belong to weathered and leached ferrallitic sandy loam soil with nutrients deficiency. The low clay fractions, organic matter/carbon, exchangeable base and cation exchange capacity of those soils had negative influence on the soil's fertility in terms to steady state nutrient supply.

Recommendation

The following are the recommendations which may help to improve the soils nutrients for optimal growing of cashew nuts;

- Regular fertilizer and compost application should be done on the farms to replenish the lost nutrients and improve the water holding capacity of the soil.
- Application of lime and dolomite to regulate pH and exchangeable bases.
- Application of organic manures and mulching.
- Changing of farming system instead of burning of cashew leaves apply a chemical that accelerate the rate of decomposition of leaves.
- Enhance good agricultural practice like avoiding tillage.
- Maintaining the pH range that influences the availability of nutrients.
- Acquire and use Regular soil fertility test tools to ensure appropriate use of fertilizers.

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APPENDICES

Appendix 1: A standard curve for Phosphate and Ammonium

Table 3: Experimental data for phosphate and Ammonium standard

	PO-4	NH+4
PPM	ABS	ABS
2		0.319
1	0.165	0.139
0.8	0.121	0.1
0.4	0.042	0.052
0.2	0.012	0.018
0.1	0.011	0.009

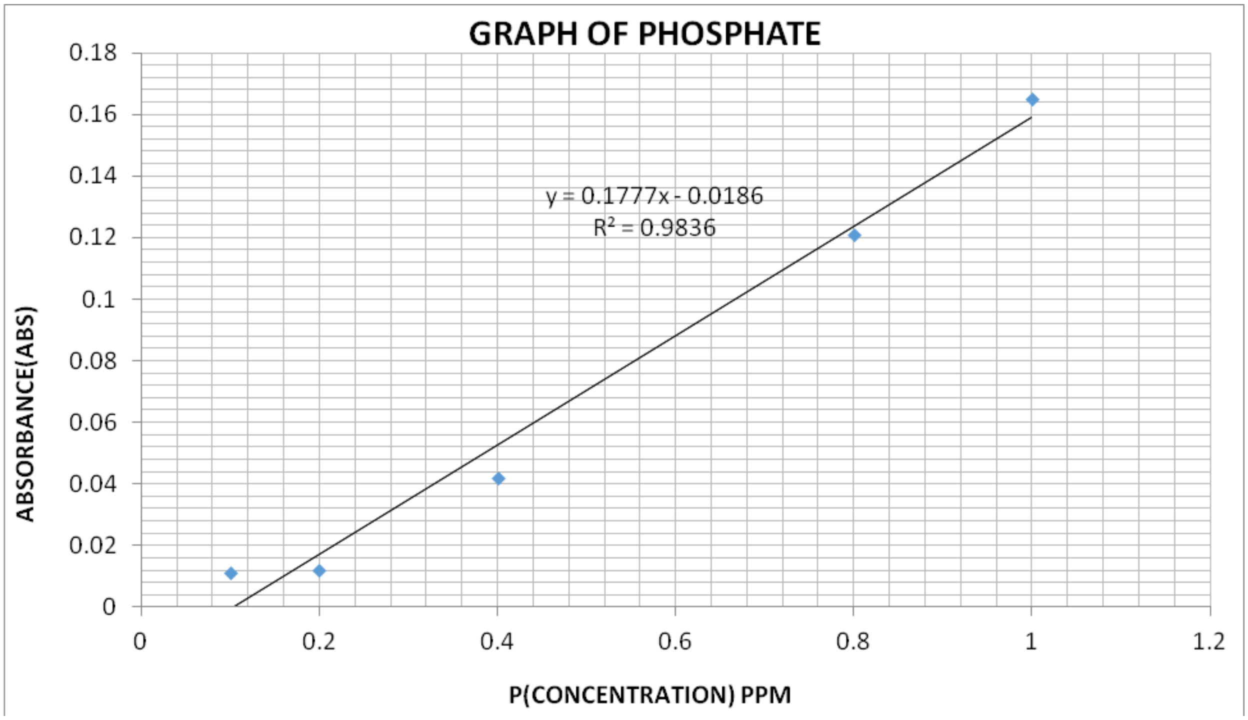

Figure 11: A plot of standard curve for Phosphate

y = 0.177x - 0.018……………………………………………………………….…Equation 2

If C = mg/l obtained from the standard calibration curve then, me /100 g is given by

$$\frac{C \times \text{Volume of extractant} \times 1000}{10000 \times sample\ weight(g) \times equivalent\ weight} \text{……………………………………………}\text{Equation 3}$$

Where;

Volume of extractant is 30ml, sample weight is 5 g, and equivalent weight is 12.16

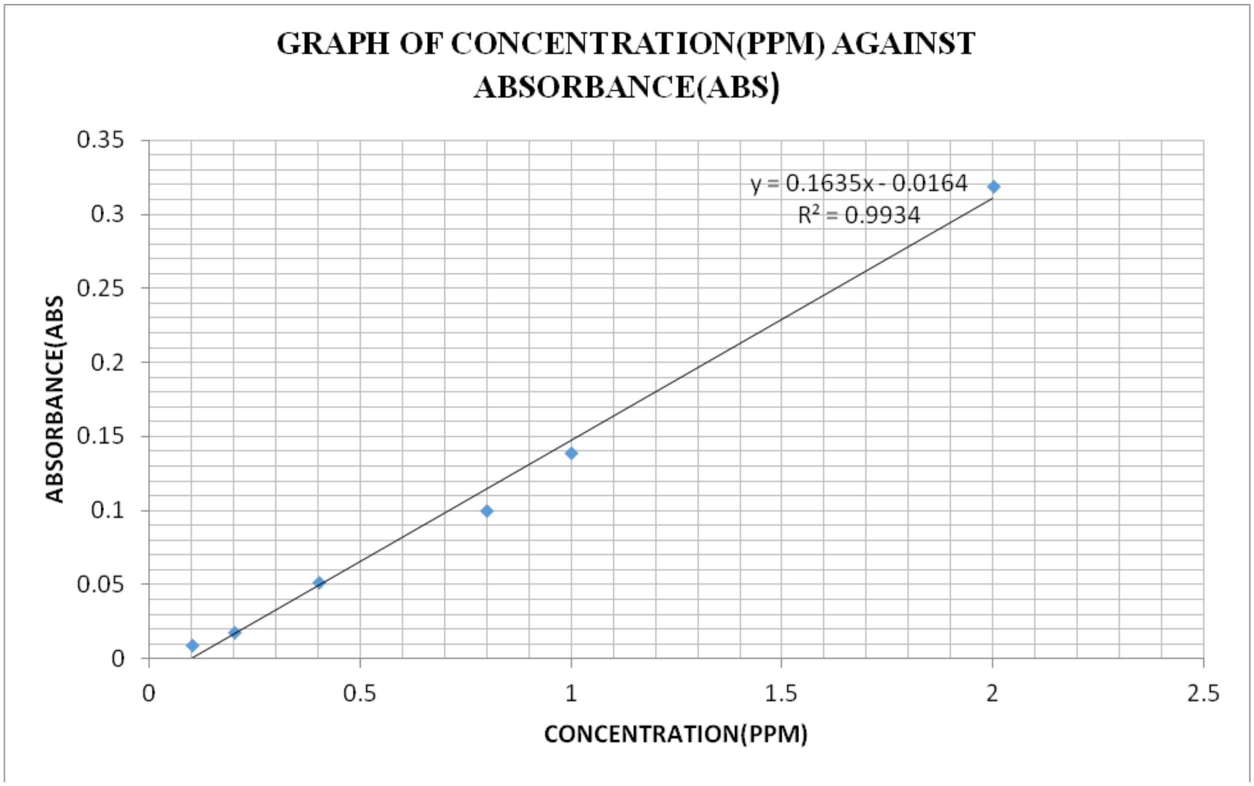

Figure 12: A plot of standard curve for Ammonium

The equation is given as y = 0.163x - 0.016……………………………………………Equation 4

From the curve, the concentration (mg/l) of sample are obtained from the equations 2 and 4 above,

If C = mg/l obtained from the standard calibration curve then

Extractable NH_4^+ (mg/100 g)

$$\text{mg/100g} = \frac{C \times \text{Volume of extractant} \times 1000}{10000 \times aliquoct \times sample\ weight(g)} \times \boldsymbol{dilution\ factor} \quad \text{.......................Equation 5}$$

Appendix 2: Equation for CEC

Then CEC is given as

$$\frac{\frac{mg}{100g}(NH4+)}{miliequivalent\ of\ NH4+} \quad \text{..Equation 6}$$

Where,

- The miliequivalent of NH_4^+ is 18
- Volume of extractant is 30 ml
- Dilution factor 30
- Aliquot is 1
- Sample weight 5g
- C varies

Appendix 3: Equation for exchangeable bases

The equation is given by

$$\frac{C \times \text{Volume of extractant} \times 1000}{10000 \times sample\ weight(g) \times equivalent\ weight} \quad \text{...Equation 7}$$

Where,

- The miliequivalent of NH_4^+ =18, Ca = 20.4, Mg =12.16, Na= 22.9 and K =39.10
- Volume of extractant is 30ml
- Sample weight 5g
- C mg/l from the curve

Appendix 4: Equation for total Nitrogen (TN) is expressed in %

TN (%) is given as

$$\frac{C \times \text{Volume of extractant}}{10000 \times sample\ weight(g)} \quad \text{.......Equation 8}$$

Where,

- C mg/l from the curve
- Volume of extractant 50ml
- Sample weight 0.1g

Appendix 5: Descriptive Statistics: EC, pH, CEC, Ca, K, Mg, Na, TN, OM, OC and P

Table 4: Statistical analysis for both 0-20cm and 20-50cm depth

Variable	N	Mean	SE Mean	StDev	Minimum	Median	Maximum
EC(μs)	48	2.982	0.215	1.487	1.310	2.490	8.350
pH	48	4.8687	0.0597	0.4136	3.5000	4.8800	6.1000
CEC(meq/100g)	48	4.032	0.208	1.438	2.184	3.650	10.446
Ca(me/100g)	48	0.08150	0.00841	0.05826	0.01299	0.10067	0.17584
K(me/100g)	48	0.08707	0.00349	0.02417	0.04203	0.08929	0.16324
Mg(me/100g)	48	0.10977	0.00388	0.02688	0.05316	0.10530	0.21200
Na(me/100g)	48	0.1204	0.0115	0.0799	0.0220	0.0744	0.2691
TN(%)	48	0.04909	0.00750	0.05197	0.00551	0.03588	0.30459
%OM	48	1.9575	0.0553	0.3833	0.8840	1.8760	3.7800
%OC	48	1.1354	0.0321	0.2223	0.5127	1.0881	2.1924
P(mg/kg)	48	2.651	0.148	1.028	1.112	2.480	5.216
P(me/100g)	48	0.02180	0.00122	0.00845	0.00915	0.02040	0.04289

Table 5: Statistical analysis for 0-20cm depth

Variable	N	Mean	SE Mean	StDev	Minimum	Median	Maximum
EC(µs)	24	3.989	0.277	1.356	1.860	3.935	8.350
pH	24	4.9979	0.0789	0.3864	4.4700	4.9400	6.1000
TN(%)	24	0.04276	0.00525	0.02570	0.00950	0.03696	0.10337
%OM	24	1.8672	0.0633	0.3101	0.8840	1.8420	2.3800
%OC	24	1.0830	0.0367	0.1799	0.5127	1.0684	1.3804
CEC(me/100g)	24	4.159	0.336	1.645	2.184	3.791	10.446
Ca(me/100g)	24	0.0625	0.0115	0.0564	0.0130	0.0212	0.1698
K(me/100g)	24	0.08717	0.00570	0.02793	0.04203	0.09125	0.16324
Mg(me/100g)	24	0.10907	0.00498	0.02440	0.08420	0.10539	0.21200
Na(me/100g)	24	0.1471	0.0184	0.0903	0.0220	0.1307	0.2691
P(mg/kg)	24	2.711	0.193	0.944	1.112	2.797	4.182
P(me/100g)	24	0.02229	0.00159	0.00777	0.00915	0.02300	0.03439

Table 6: Statistical analysis for 20-50cm depth

Variable	N	Mean	SE Mean	StDev	Minimum	Median	Maximum
EC(µs)	24	1.975	0.154	0.753	1.310	1.750	5.090
pH	24	4.7396	0.0830	0.4068	3.5000	4.8100	5.4300
TN(%)	24	0.0554	0.0141	0.0691	0.0055	0.0342	0.3046
%OM	24	2.0479	0.0883	0.4325	1.5780	1.9960	3.7800
%OC	24	1.1878	0.0512	0.2509	0.9152	1.1577	2.1924
CEC(meq/100g)	24	3.905	0.249	1.218	2.233	3.601	7.552
Ca (me/100g)	24	0.1005	0.0112	0.0548	0.0134	0.1156	0.1758
K(me/100g)	24	0.08697	0.00415	0.02035	0.04897	0.08900	0.12756
Mg(me/100g)	24	0.11047	0.00606	0.02967	0.05316	0.10429	0.19793
Na(me/100g)	24	0.0937	0.0119	0.0583	0.0596	0.0717	0.2678

P(mg/kg)	24	2.591	0.229	1.122	1.179	2.147	5.216
P(me/100g)	24	0.02131	0.00188	0.00923	0.00970	0.01765	0.04289

Table 7: Statistical analysis for profile

Variable	N	Mean	SE Mean	StDev	Minimum	Median	Maximum
EC(µs)	5	2.768	0.159	0.357	2.310	2.770	3.140
pH	5	5.132	0.102	0.229	4.870	5.080	5.470
TN(%)	5	0.03134	0.00875	0.01957	0.01625	0.01932	0.06073
%OM	5	3.180	0.247	0.551	2.358	3.320	3.780
%OC	5	1.844	0.143	0.320	1.368	1.926	2.192
CEC(meq/100g)	5	3.395	0.351	0.784	2.172	3.534	4.227
Ca (me/100g)	5	0.0948	0.0229	0.0513	0.0380	0.1233	0.1376
K(me/100g)	5	0.1188	0.0122	0.0274	0.0846	0.1105	0.1479
Mg(me/100g)	5	0.11011	0.00298	0.00666	0.09940	0.11123	0.11672
Na(me/100g)	5	0.1167	0.0373	0.0833	0.0603	0.0728	0.2585
P(mg/kg)	5	2.020	0.463	1.035	1.212	1.446	3.681
P(me/100g)	5	0.01661	0.00380	0.00851	0.00997	0.01189	0.03027

Table 8: Statistical analysis for AC4 variety

Variable	N	Mean	SE Mean	StDev	Minimum	Median	Maximum
EC(µs)	24	3.187	0.349	1.708	1.310	2.555	8.350
pH	24	4.7987	0.0814	0.3988	3.5000	4.8650	5.3900
TN(%)	24	0.0642	0.0138	0.0674	0.0098	0.0445	0.3046
%OM	24	1.8870	0.0625	0.3060	0.8840	1.8630	2.3340
%OC	24	1.0945	0.0362	0.1775	0.5127	1.0805	1.3537
CEC(meq/100g)	24	3.934	0.218	1.066	2.184	3.610	6.540
Ca (me/100g)	24	0.0745	0.0116	0.0568	0.0130	0.0981	0.1676
K(me/100g)	24	0.08241	0.00571	0.02795	0.04203	0.08213	0.16324

Mg(me/100g)	24	0.10181	0.00294	0.01438	0.05316	0.10391	0.12065
Na(me/100g)	24	0.1045	0.0139	0.0679	0.0220	0.0723	0.2678
P(mg/kg)	24	2.650	0.189	0.927	1.179	2.480	4.182
P(me/100g)	24	0.02179	0.00156	0.00762	0.00970	0.02040	0.03439

Table 9: Statistical analysis for AZA2 variety

Variable	N	Mean	SE Mean	StDev	Minimum	Median	Maximum
EC(μs)	24	2.777	0.251	1.232	1.470	2.380	6.390
pH	24	4.9387	0.0867	0.4247	4.3600	4.9000	6.1000
TN(%)	24	0.03399	0.00454	0.02225	0.00551	0.03143	0.09110
%OM	24	2.0281	0.0904	0.4430	1.4460	1.9580	3.7800
%OC	24	1.1763	0.0525	0.2570	0.8387	1.1356	2.1924
CEC(meq/100g)	24	4.130	0.358	1.752	2.233	3.672	10.446
Ca (me/100g)	24	0.0885	0.0123	0.0601	0.0144	0.1095	0.1758
K(me/100g)	24	0.09172	0.00391	0.01917	0.05855	0.09320	0.12805
Mg(me/100g)	24	0.11773	0.00688	0.03372	0.08812	0.10622	0.21200
Na(me/100g)	24	0.1363	0.0181	0.0889	0.0379	0.0841	0.2691
P(mg/kg)	24	2.653	0.233	1.139	1.112	2.463	5.216
P(me/100g)	24	0.02181	0.00191	0.00937	0.00915	0.02026	0.04289

Appendix 6: A graph summary for profile

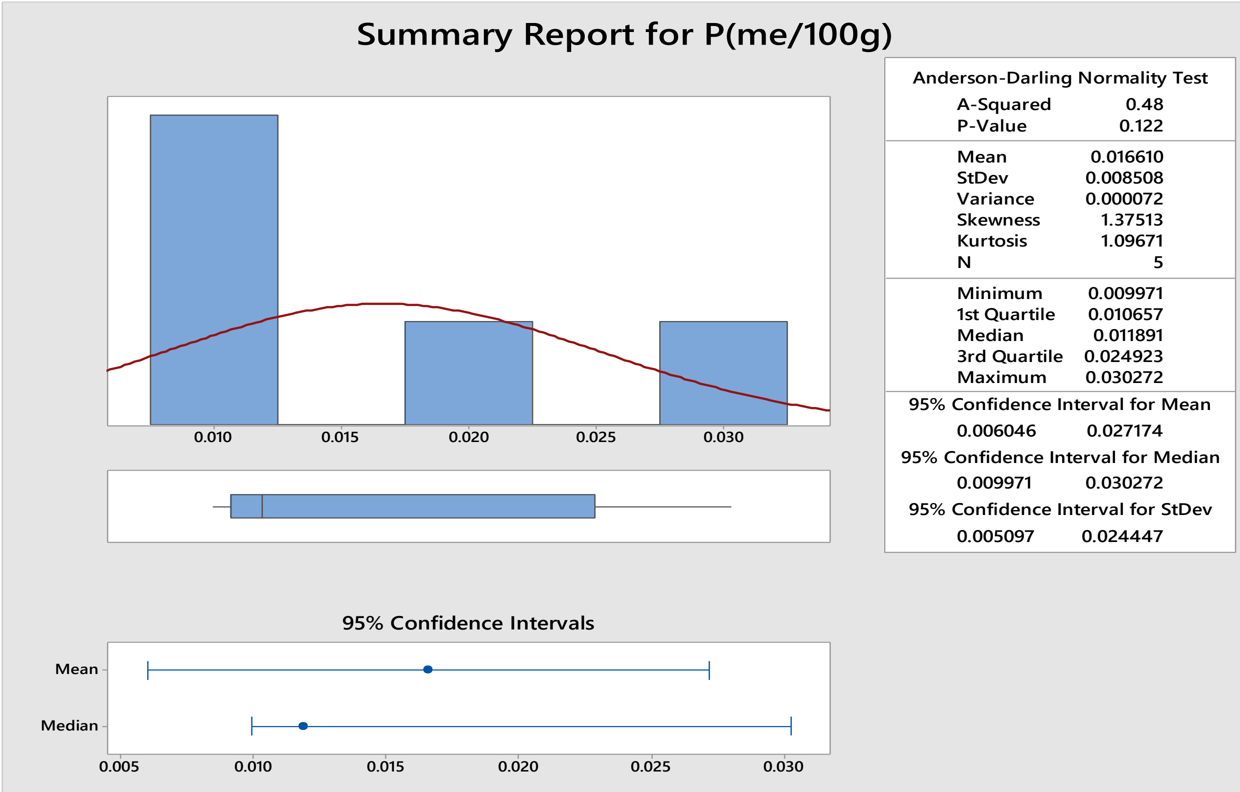

Figure 13: Analysis of P for soil profile

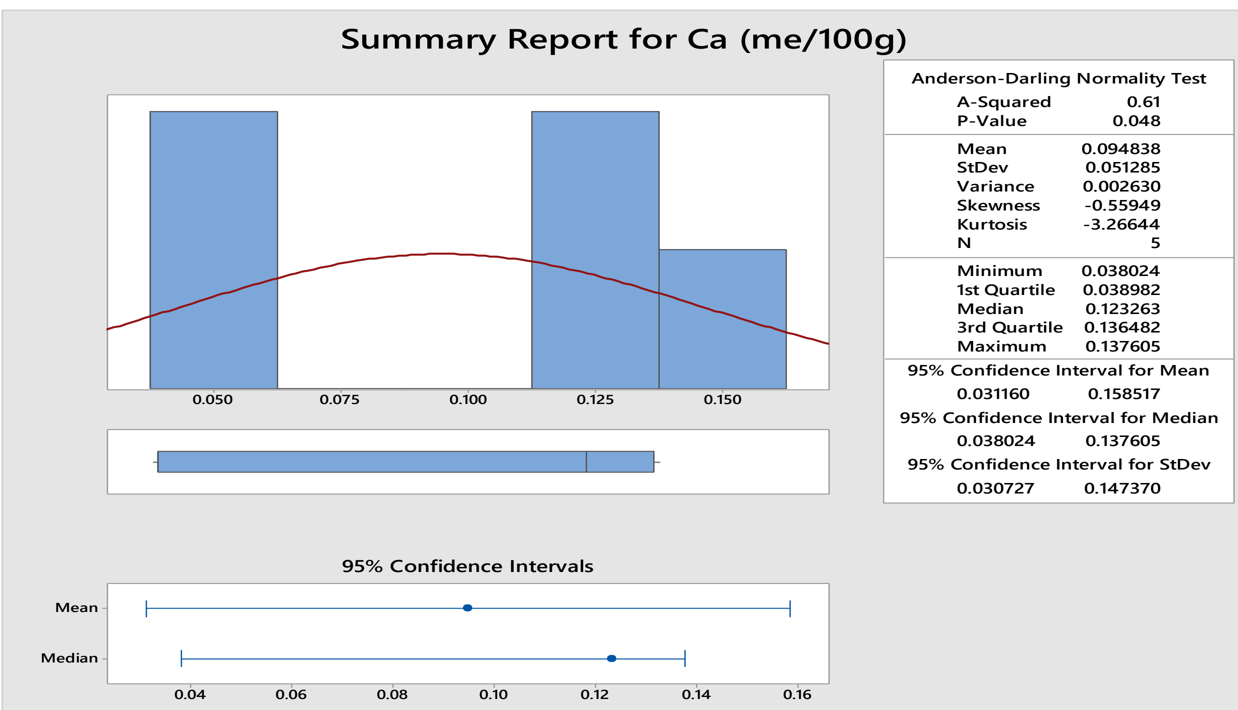

Figure 14: Analysis of Ca for soil profile

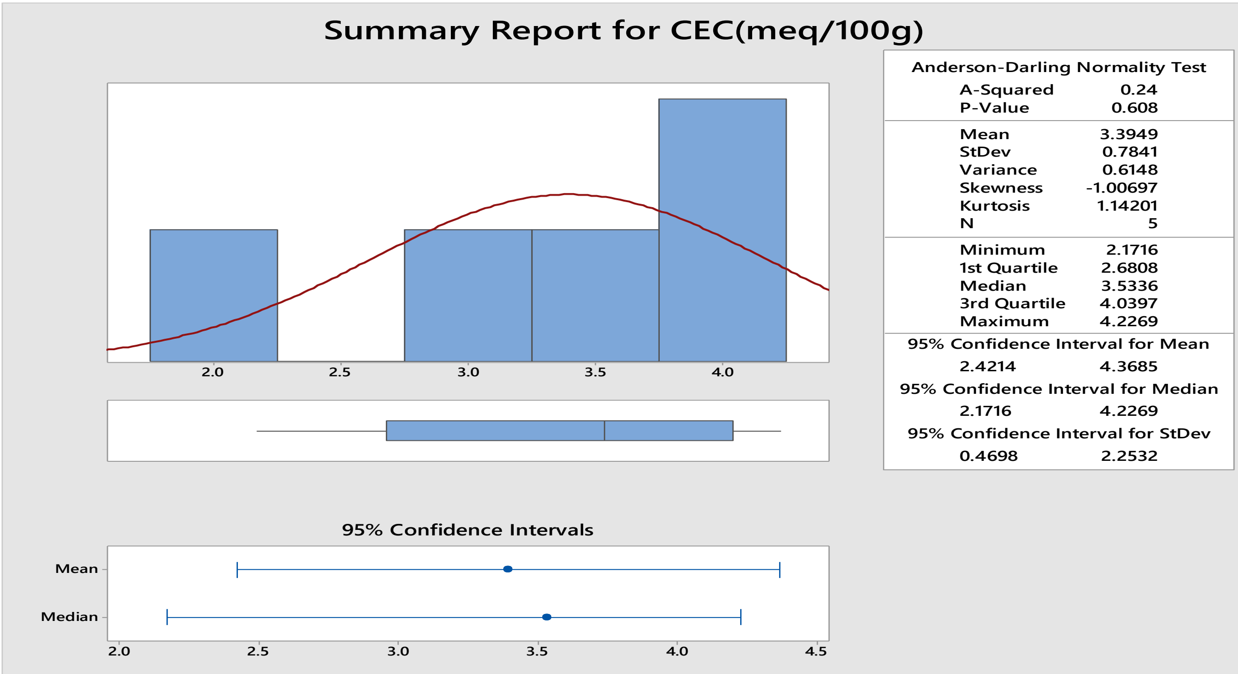

Figure 15: Analysis of CEC for soil profile

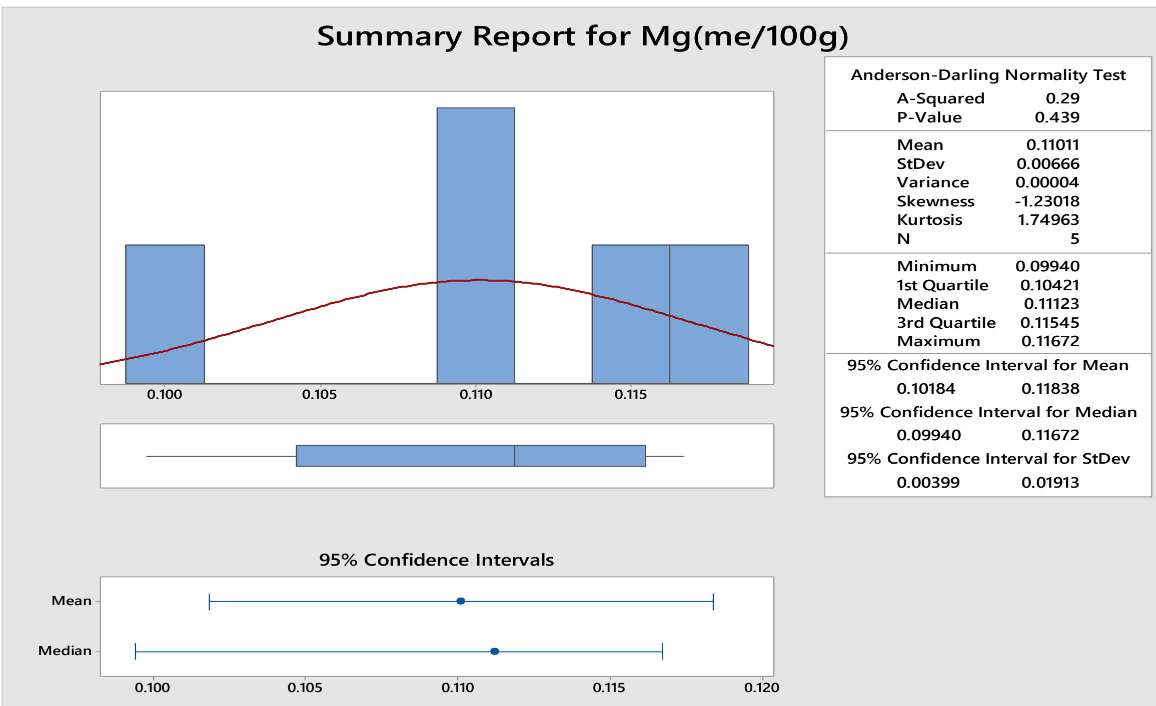

Figure 16: Analysis of Mg for soil profile

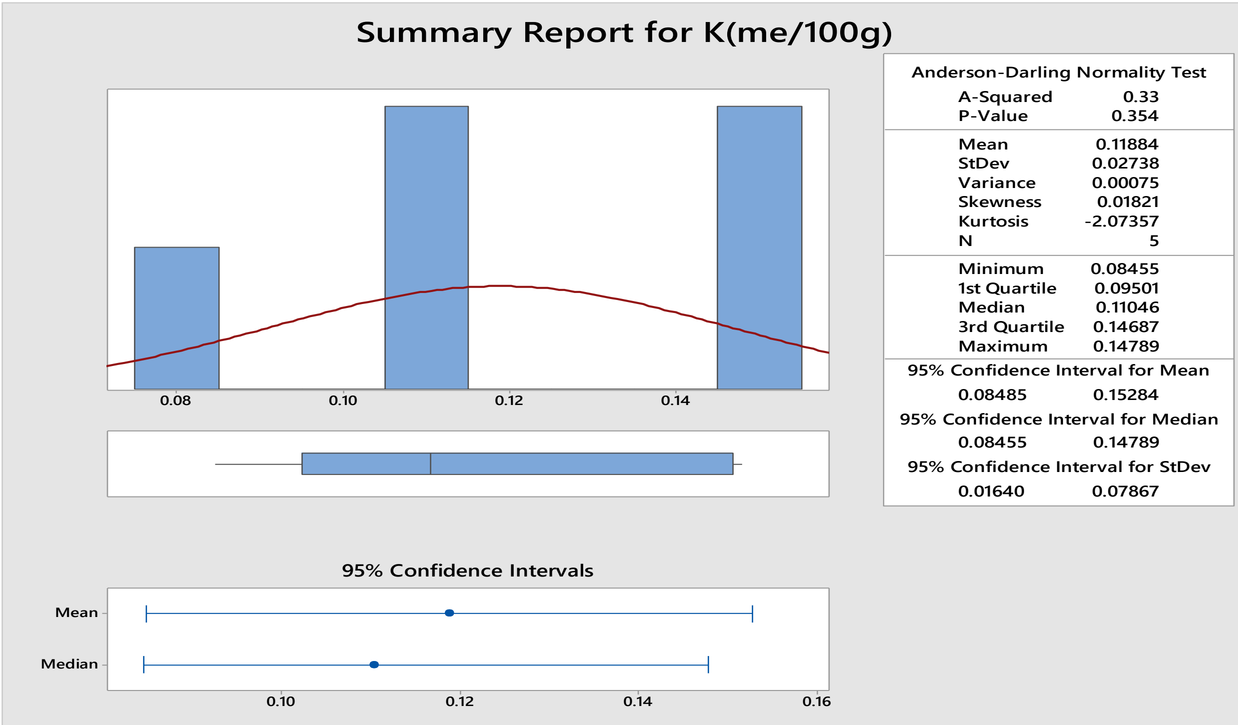

Figure 17: Analysis of K for soil profile

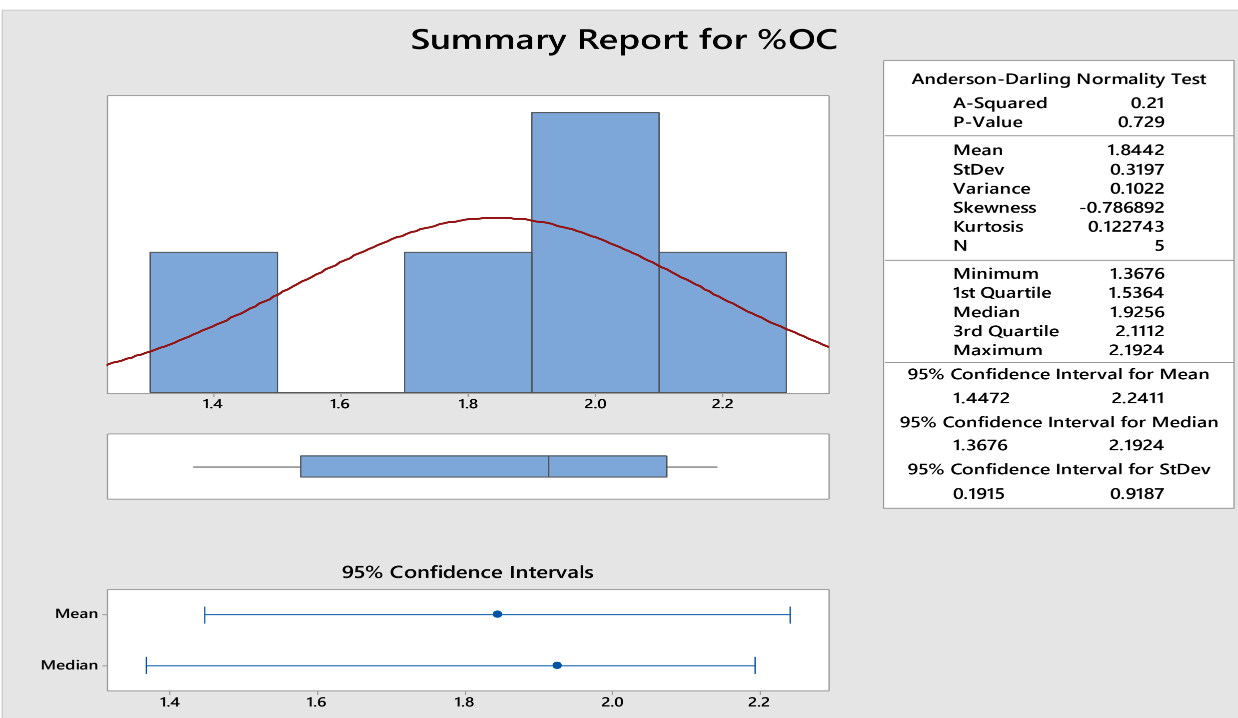

Figure 18: Analysis of % OC for soil profile

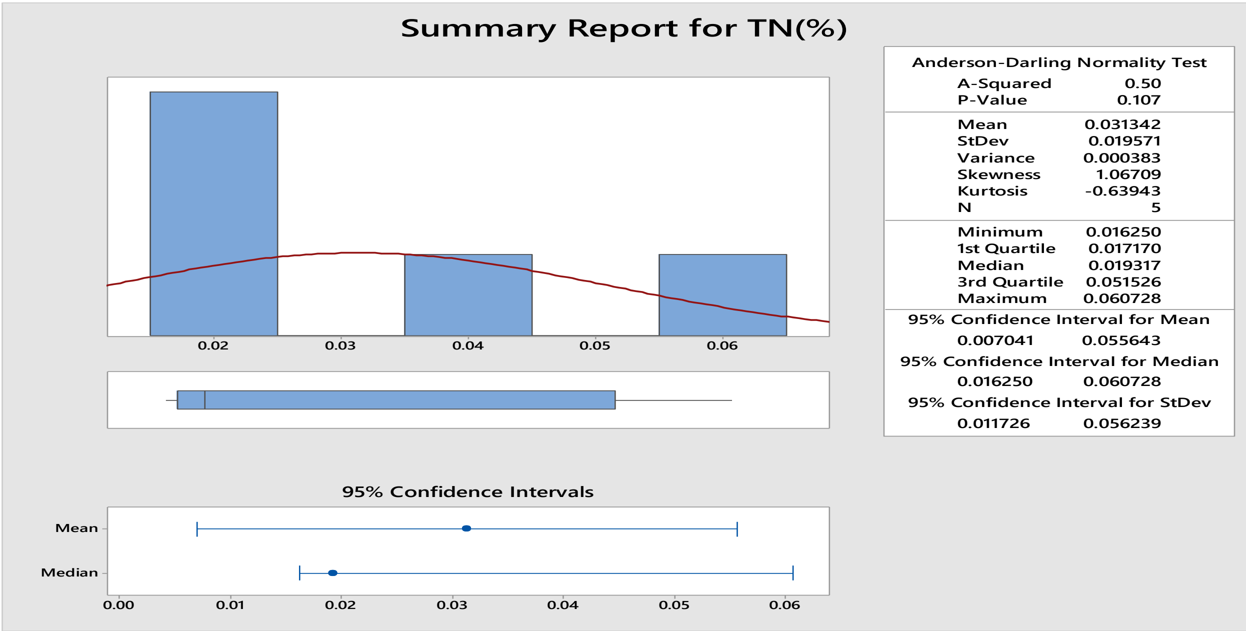

Figure 19: Analysis of %TN for soil profile

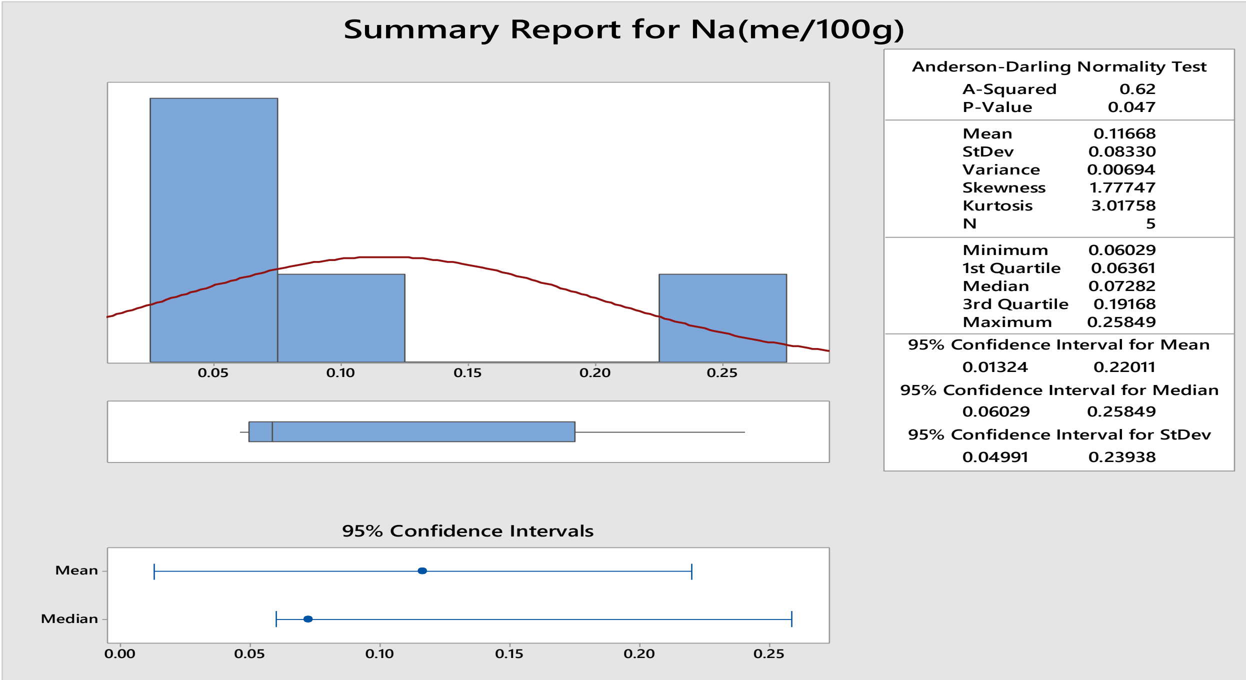

Figure 20: Analysis of Na for soil profile

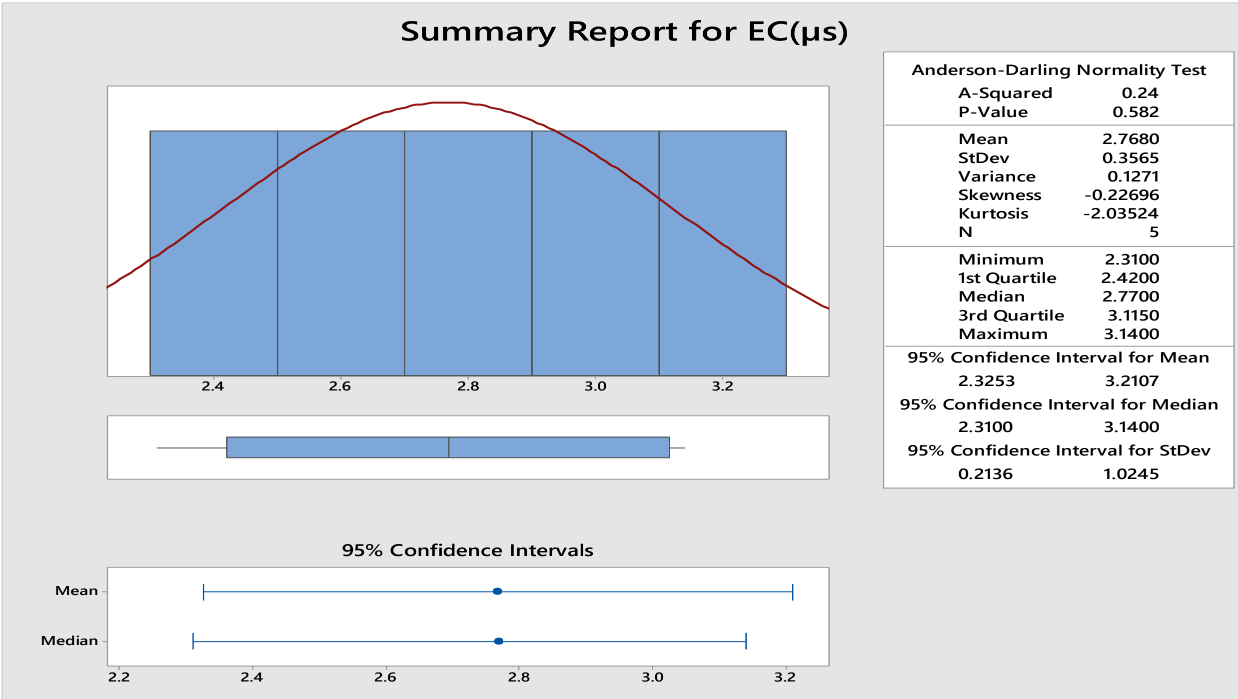

Figure 21: Analysis of EC for soil profile

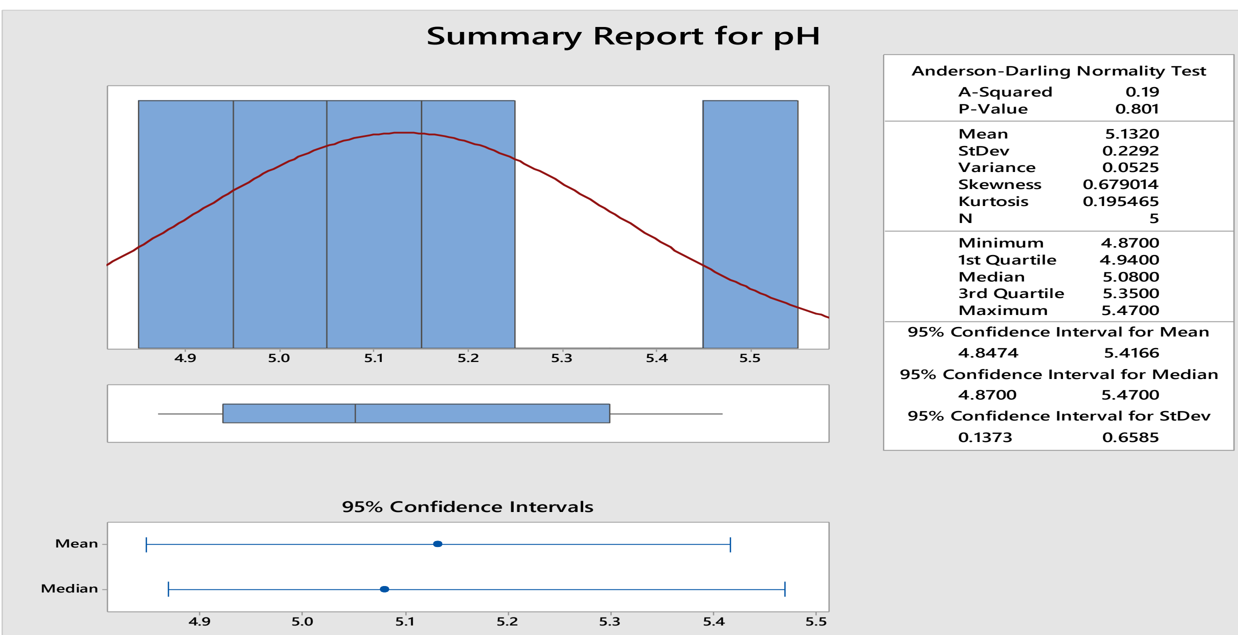

Figure 22: Analysis of pH for soil profile

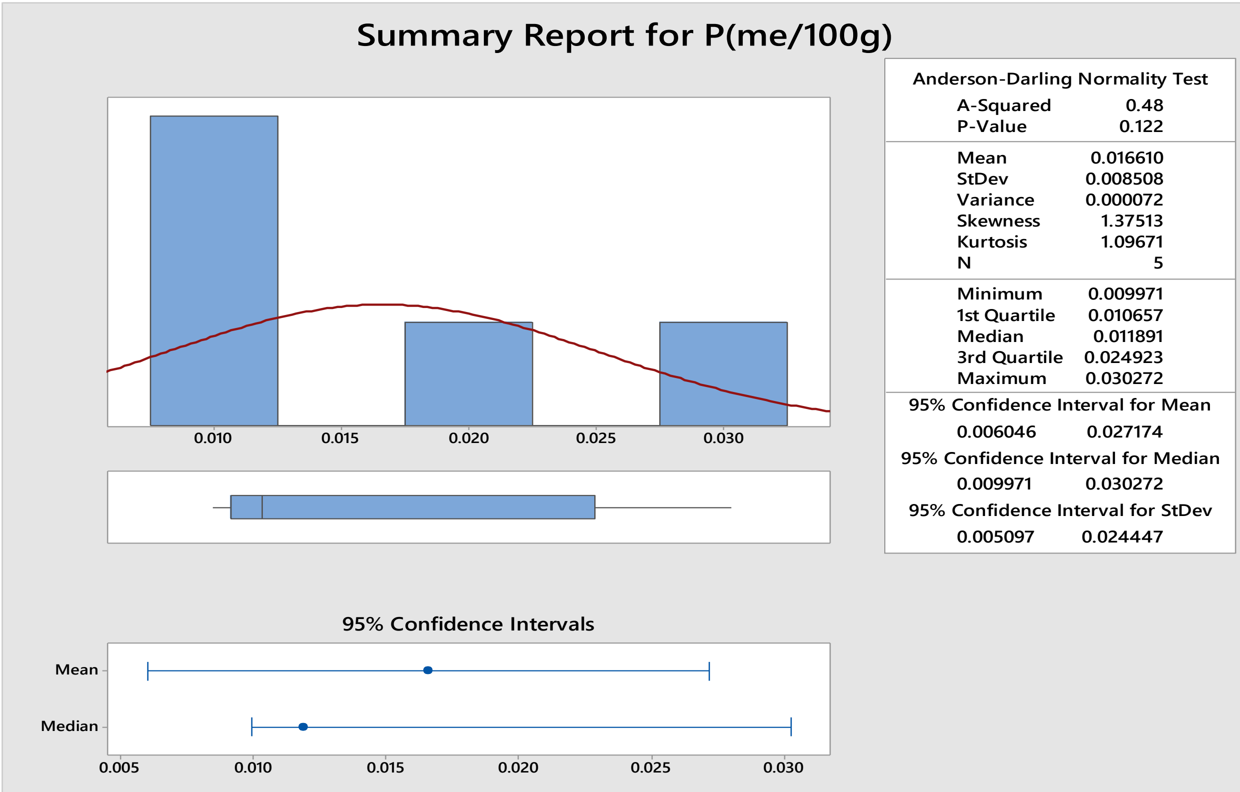

Figure 23: Analysis of P for soil profile

Table 10: Plan of work

S/N	DESCRIPTION OF WORK	DURATION IN WEEK							
		1	2	3	4	5	6	7	8+
1	Introduction on cashew farming								
2	Formulation of problem statement								
3	Formulation of Objectives								
4	Literature review								
5	Presentation to UDIEC staff and Supervisors								
6	Review and selection of Technologies								
7	Visit to Mtwara-NARI								
9	Presentation to NARI staff								
10	Data collection								
11	Soil sampling								
12	Study/Learning activities conducted at NARI								
13	Soil analysis at UDSM								
14	Data analysis at UDSM								
15	Writing of Results								

	and discussion								
16	Development of tool								
17	Conclusion								
18	Recommendation								
19	Presentation of final report								

Table 11: Raw data

S/N	Sample code	EC (µs)	pH (H_2O)	P (ABS)	P (ppm)	N (ABS)	N (ppm)	CEC (ABS)	CEC (ppm)	OM (W1 g)	OM (W2 g)	Ca (ppm)	K (ppm)	Na (ppm)	Na (ppm)	Mg (ppm)
1	B1/AC4/T1/50	5.09	4.62	0.079	0.541	0.252	1.644	0.675	4.239	5	4.907	3.603	1.09	0.693	2.843	2.04
2	B1/AC4/T2/50	2.61	3.5	0.017	0.197	0.697	4.374	0.576	3.632	5	4.911	3.241	0.501	0.642	2.634	1.76
3	B1/AC4/T3/50	1.67	4.09	0.075	0.519	0.286	1.853	0.527	3.331	5	4.920	5.389	0.8335	0.671	2.753	2.45
4	B1/AC4/T2/20	4.75	4.75	0.107	0.697	0.216	1.423	0.594	3.742	5	4.906	3.938	0.649	0.699	2.868	1.83
5	B1/AC4/T1/20	3.95	4.47	0.072	0.502	0.212	1.399	0.569	3.589	5	4.956	3.411	0.789	1.43	1.430	2.34
6	B1/AC4/T3/20	3.34	5.08	0.084	0.569	0.124	0.859	0.673	4.227	5	4.920	5.016	0.663	0.557	2.285	2.035
7	B1/AZA2/T1/20	4.4	5.68	0.07	0.491	0.14	0.957	0.301	1.945	5	4.911	5.67	0.916	2.513	10.311	2.42
8	B1/AZA2/T1/50	1.91	5.43	0.062	0.447	0.182	1.215	1.215	7.552	5	4.891	4.591	0.824	0.637	2.614	2.089
9	B1/AZA2/T2/20	4.24	5.44	0.063	0.452	0.267	1.736	0.429	2.730	5	4.928	2.915	0.599	0.651	2.671	1.798
10	B1/AZA2/T2/50	2.31	5.04	0.101	0.664	0.159	1.073	0.578	3.644	5	4.921	3.78	0.805	0.646	2.651	1.992
11	B1/AZA2/T3/20	3.07	5.07	0.102	0.669	0.053	0.423	0.656	4.123	5	4.914	3.532	0.604	2.513	10.311	1.997
12	B1/AZA2/T3/50	1.63	4.81	0.041	0.330	0.091	0.656	0.484	3.067	5	4.910	3.13	0.62	0.668	2.741	2.045
13	B2/AC4/T1/20	4.04	4.96	0.091	0.608	0.016	0.196	0.562	3.546	5	4.910	3.314	0.43	0.676	2.774	1.707
14	B2/AC4/T1/50	1.84	4.96	0.042	0.336	0.145	0.988	0.541	3.417	5	4.910	3.772	0.572	0.63	2.585	1.922
15	B2/AC4/T2/20	4.69	5.14	0.048	0.369	0.185	1.233	0.55	3.472	5	4.905	0.434	0.594	0.644	2.642	2.125
16	B2/AC4/T2/50	2.19	4.94	0.101	0.664	0.232	1.521	0.566	3.570	5	4.920	3.855	0.741	2.501	10.262	1.077
17	B2/AC4/T3/20	3.68	4.73	0.106	0.691	0.115	0.804	0.447	2.840	5	4.909	3.922	0.447	0.697	2.860	1.843
18	B2/AC4/T3/50	1.67	4.87	0.027	0.252	0.977	6.092	0.533	3.368	5	4.883	4.482	0.553	1.468	6.023	1.987

19	B2/AZA2/T1/20	6.39	4.65	0.029	0.263	0.281	1.822	0.648	4.073	5	4.881	0.576	0.786	1.451	1.451	2.235
20	B2/AZA2/T1/50	2.31	4.43	0.019	0.208	0.092	0.662	0.348	2.233	5	4.898	3.993	0.813	2.485	10.196	2.032
21	B2/AZA2/T2/20	2.59	4.62	0.098	0.647	0.11	0.773	0.567	3.577	5	4.888	5.477	0.72	1.532	6.286	2.022
22	B2/AZA2/T2/50	1.68	4.59	0.028	0.258	0.038	0.331	0.534	3.374	5	4.811	4.202	0.865	0.583	2.392	2.093
23	B2/AZA2/T3/20	3.22	5.05	0.015	0.185	0.08	0.589	0.69	4.331	5	4.916	0.523	0.9804	2.497	10.245	2.334
24	B2/AZA2/T3/50	1.8	4.74	0.04	0.324	0.038	0.331	0.585	3.687	5	4.908	5.189	1.0715	0.637	2.614	2.148
25	B3/AC4/T1/20	8.35	5.29	0.027	0.252	0.057	0.448	1.05	6.540	5	4.890	0.682	1.67	1.906	7.820	2.414
26	B3/AC4/T1/50	2.48	4.75	0.102	0.669	0.032	0.294	0.736	4.613	5	4.897	4	0.91	0.674	2.765	2.025
27	B3/AC4/T2/20	4.33	4.52	0.05	0.380	0.087	0.632	0.833	5.208	5	4.889	0.611	1.168	0.205	0.841	2.134
28	B3/AC4/T2/50	1.39	5.39	0.056	0.413	0.099	0.705	0.737	4.619	5	4.907	5.597	0.661	0.557	2.285	2.064
29	B3/AC4/T3/20	1.86	5.18	0.032	0.280	0.089	0.644	0.61	3.840	5	4.912	0.562	0.976	2.033	8.341	2.087
30	B3/AC4/T3/50	1.7	5.13	0.039	0.319	0.171	1.147	0.758	4.748	5	4.899	0.485	1.081	0.565	2.318	2.243
31	B3/AZA2/T1/20	3.36	6.1	0.025	0.241	0.082	0.601	0.739	4.632	5	4.907	0.571	1.31	2.511	10.303	1.786
32	B3/AZA2/T1/50	2	4.99	0.042	0.336	0.013	0.178	0.489	3.098	5	4.903	4.181	1.305	0.687	2.819	2.35
33	B3/AZA2/T2/20	3.92	5.39	0.049	0.374	0.015	0.190	0.699	4.386	5	4.912	0.671	0.951	2.466	10.118	2.263
34	B3/AZA2/T2/50	1.61	5.01	0.074	0.513	0.05	0.405	0.866	5.411	5	4.906	0.482	0.938	0.82	3.364	2.349
35	B3/AZA2/T3/20	4.36	4.55	0.09	0.602	0.103	0.730	0.816	5.104	5	4.895	0.593	1.114	2.434	9.987	2.368
36	B3/AZA2/T3/50	1.47	4.36	0.138	0.869	0.061	0.472	0.748	4.687	5	4.888	4.93	1.168	0.617	2.532	2.368
37	B4/AC4/T1/20	4.72	4.98	0.058	0.424	0.097	0.693	0.754	4.724	5	4.912	0.772	1.022	1.968	8.075	2.424
38	B4/AC4/T1/50	1.31	4.86	0.056	0.413	0.017	0.202	1.017	6.337	5	4.889	0.489	0.954	0.611	2.507	2.219
39	B4/AC4/T2/20	2.5	4.66	0.076	0.525	0.321	2.067	0.34	2.184	5	4.910	0.529	0.847	1.828	7.500	2.257

40	B4/AC4/T2/50	1.42	4.81	0.024	0.235	0.134	0.920	0.455	2.889	5	4.888	0.447	0.911	0.685	2.811	2.207
41	B4/AC4/T3/20	4.89	4.92	0.055	0.408	0.059	0.460	0.5011	3.172	5	4.889	0.719	1.042	1.521	6.241	2.207
42	B4/AC4/T3/50	2.01	4.57	0.042	0.336	0.019	0.215	0.401	2.558	5	4.896	0.457	1.13	0.636	2.610	2.134
43	B4/AZA2/T1/20	2.97	4.92	0.073	0.508	0.132	0.908	0.405	2.583	5	4.906	0.58	1.054	0.921	3.779	2.138
44	B4/AZA2/T1/50	1.48	4.58	0.045	0.352	0.06	0.466	0.493	3.123	5	4.901	3.865	0.982	1.341	5.502	2.157
45	B4/AZA2/T2/20	3.66	4.91	0.068	0.480	0.015	0.190	0.475	3.012	5	4.894	0.699	1.114	0.776	3.184	1.997
46	B4/AZA2/T2/50	2.17	4.43	0.047	0.363	0.002	0.110	0.452	2.871	5	4.880	5.873	1.001	0.752	3.085	3.975
47	B4/AZA2/T3/20	2.45	4.89	0.022	0.224	0.106	0.748	0.592	3.730	5	4.900	4.379	0.956	0.717	2.942	4.297
48	B4/AZA2/T3/50	1.64	4.85	0.127	0.808	0.106	0.748	0.58	3.656	5	4.898	0.526	1.023	0.795	3.262	4.011
49	Ap(0-36)	3.14	5.47	0.092	0.614	0.182	1.215	0.673	4.227	5	4.811	1.27	1.513	1.166	4.784	2.366
50	BA(36-88)	2.31	5.08	0.023	0.230	0.122	0.846	0.56	3.534	5	4.882	1.334	0.865	0.625	2.564	2.01 46
51	BW1(88-137)	2.77	4.87	0.018	0.202	0.043	0.362	0.612	3.853	5	4.834	4.117	1.492	2.414	9.905	2.209
52	BW2(137-171)	3.09	5.23	0.025	0.241	0.037	0.325	0.338	2.172	5	4.853	4.521	1.079	0.563	2.310	2.314
53	BW3(171-200+	2.53	5.01	0.053	0.397	0.047	0.386	0.504	3.190	5	4.825	4.596	1.13	0.68	2.790	2.254

Table 12: Processed data

S/N	Sample code	EC (µs)	pH	TN (%)	OM (%)	OC (%)	CEC (me/100g)	Ca (me/100g)	K (me/100g)	Mg (me/100g)	Na (me/100g)	P (mg/kg)	P (me/100g)
1	B1/AC4/T1/50	5.09	4.62	0.082	1.866	1.082	4.239	0.108	0.107	0.101	0.074	3.247	0.0267
2	B1/AC4/T2/50	2.61	3.5	0.219	1.78	1.032	3.632	0.097	0.049	0.087	0.069	1.179	0.0097
3	B1/AC4/T3/50	1.67	4.09	0.093	1.604	0.930	3.331	0.161	0.081	0.121	0.072	3.114	0.0256
4	B1/AC4/T2/20	4.75	4.75	0.071	1.874	1.087	3.742	0.118	0.063	0.090	0.075	4.182	0.0344
5	B1/AC4/T1/20	3.95	4.47	0.07	0.884	0.513	3.589	0.102	0.077	0.115	0.037	3.014	0.0248
6	B1/AC4/T3/20	3.34	5.08	0.043	1.608	0.933	4.227	0.150	0.065	0.100	0.060	3.414	0.0281
7	B1/AZA2/T1/20	4.4	5.68	0.048	1.778	1.031	10.446	0.170	0.090	0.119	0.269	2.947	0.0242
8	B1/AZA2/T1/50	1.91	5.43	0.061	2.184	1.267	7.552	0.137	0.081	0.103	0.068	2.680	0.0220
9	B1/AZA2/T2/20	4.24	5.44	0.087	1.446	0.839	2.730	0.087	0.059	0.089	0.070	2.714	0.0223
10	B1/AZA2/T2/50	2.31	5.04	0.054	1.578	0.915	3.644	0.113	0.079	0.098	0.069	3.981	0.0327
11	B1/AZA2/T3/20	3.07	5.07	0.021	1.72	0.998	4.123	0.106	0.059	0.099	0.269	4.015	0.0330
12	B1/AZA2/T3/50	1.63	4.81	0.033	1.81	1.050	3.067	0.094	0.061	0.101	0.072	1.980	0.0163
13	B2/AC4/T1/20	4.04	4.96	0.01	1.794	1.041	3.546	0.099	0.042	0.084	0.072	3.648	0.0300
14	B2/AC4/T1/50	1.84	4.96	0.049	1.794	1.041	3.417	0.113	0.056	0.095	0.067	2.013	0.0166
15	B2/AC4/T2/20	4.69	5.14	0.062	1.896	1.100	3.472	0.013	0.058	0.105	0.069	2.213	0.0182
16	B2/AC4/T2/50	2.19	4.94	0.076	1.594	0.925	3.570	0.115	0.072	0.053	0.268	3.981	0.0327
17	B2/AC4/T3/20	3.68	4.73	0.04	1.816	1.053	2.840	0.117	0.044	0.091	0.075	4.148	0.0341
18	B2/AC4/T3/50	1.67	4.87	0.305	2.334	1.354	3.368	0.134	0.054	0.098	0.157	1.513	0.0124

19	B2/AZA2/T1/20	6.39	4.65	0.091	2.38	1.380	4.073	0.017	0.077	0.110	0.038	1.579	0.0130
20	B2/AZA2/T1/50	2.31	4.43	0.033	2.032	1.179	2.233	0.120	0.079	0.100	0.266	1.246	0.0102
21	B2/AZA2/T2/20	2.59	4.62	0.039	2.238	1.298	3.577	0.164	0.070	0.100	0.164	3.881	0.0319
22	B2/AZA2/T2/50	1.68	4.59	0.017	3.78	2.192	3.374	0.126	0.085	0.103	0.062	1.546	0.0127
23	B2/AZA2/T3/20	3.22	5.05	0.029	1.678	0.973	4.331	0.016	0.096	0.115	0.267	1.112	0.0091
24	B2/AZA2/T3/50	1.8	4.74	0.017	1.844	1.070	3.687	0.155	0.105	0.106	0.068	1.946	0.0160
25	B3/AC4/T1/20	8.35	5.29	0.022	2.2	1.276	6.540	0.020	0.163	0.119	0.204	1.513	0.0124
26	B3/AC4/T1/50	2.48	4.75	0.015	2.062	1.196	4.613	0.120	0.089	0.100	0.072	4.015	0.0330
27	B3/AC4/T2/20	4.33	4.52	0.032	2.222	1.289	5.208	0.018	0.114	0.105	0.022	2.280	0.0188
28	B3/AC4/T2/50	1.39	5.39	0.035	1.86	1.079	4.619	0.168	0.065	0.102	0.060	2.480	0.0204
29	B3/AC4/T3/20	1.86	5.18	0.032	1.758	1.020	3.840	0.017	0.095	0.103	0.218	1.680	0.0138
30	B3/AC4/T3/50	1.7	5.13	0.057	2.02	1.172	4.748	0.015	0.106	0.111	0.061	1.913	0.0157
31	B3/AZA2/T1/20	3.36	6.1	0.03	1.868	1.083	4.632	0.017	0.128	0.088	0.269	1.446	0.0119
32	B3/AZA2/T1/50	2	4.99	0.009	1.944	1.128	3.098	0.125	0.128	0.116	0.074	2.013	0.0166
33	B3/AZA2/T2/20	3.92	5.39	0.01	1.768	1.025	4.386	0.020	0.093	0.112	0.264	2.247	0.0185
34	B3/AZA2/T2/50	1.61	5.01	0.02	1.874	1.087	5.411	0.014	0.092	0.116	0.088	3.081	0.0253
35	B3/AZA2/T3/20	4.36	4.55	0.036	2.096	1.216	5.104	0.018	0.109	0.117	0.261	3.614	0.0297
36	B3/AZA2/T3/50	1.47	4.36	0.024	2.248	1.304	4.687	0.148	0.114	0.117	0.066	5.216	0.0429
37	B4/AC4/T1/20	4.72	4.98	0.035	1.768	1.025	4.724	0.023	0.100	0.120	0.211	2.547	0.0209
38	B4/AC4/T1/50	1.31	4.86	0.01	2.216	1.285	6.337	0.015	0.093	0.110	0.065	2.480	0.0204
39	B4/AC4/T2/20	2.5	4.66	0.103	1.81	1.050	2.184	0.016	0.083	0.111	0.196	3.147	0.0259

40	B4/AC4/T2/50	1.42	4.81	0.046	2.234	1.296	2.889	0.013	0.089	0.109	0.073	1.413	0.0116
41	B4/AC4/T3/20	4.89	4.92	0.023	2.216	1.285	3.172	0.022	0.102	0.109	0.163	2.447	0.0201
42	B4/AC4/T3/50	2.01	4.57	0.011	2.078	1.205	2.558	0.014	0.110	0.105	0.068	2.013	0.0166
43	B4/AZA2/T1/20	2.97	4.92	0.045	1.878	1.089	2.583	0.017	0.103	0.105	0.099	3.047	0.0251
44	B4/AZA2/T1/50	1.48	4.58	0.023	1.972	1.144	3.123	0.116	0.096	0.106	0.144	2.113	0.0174
45	B4/AZA2/T2/20	3.66	4.91	0.01	2.118	1.228	3.012	0.021	0.109	0.099	0.083	2.880	0.0237
46	B4/AZA2/T2/50	2.17	4.43	0.006	2.4	1.392	2.871	0.176	0.098	0.196	0.081	2.180	0.0179
47	B4/AZA2/T3/20	2.45	4.89	0.037	1.998	1.159	3.730	0.131	0.093	0.212	0.077	1.346	0.0111
48	B4/AZA2/T3/50	1.64	4.85	0.037	2.042	1.184	3.656	0.016	0.100	0.198	0.085	4.849	0.0399

Table 13: Profile results

S/N	Sample code	EC (µs)	pH	TN (%)	OM %	OC %	CEC (me/100g)	Ca (me/100g)	K (me/100g)	Mg (me/100g)	Na (me/100g)	P (mg/kg)	P (me/100g)
1	Ap(0-36)	3.14	5.47	0.061	3.78	2.19	4.227	0.038	0.148	0.117	0.125	3.681	0.0303
2	BA(36-88)	2.31	5.08	0.042	2.358	1.37	3.534	0.040	0.085	0.099	0.067	1.379	0.0113
3	BW1(88-137)	2.77	4.87	0.018	3.32	1.93	3.853	0.123	0.146	0.109	0.258	1.212	0.0100
4	BW2(137-171)	3.09	5.23	0.016	2.94	1.71	2.172	0.135	0.105	0.114	0.060	1.446	0.0119
5	BW3(171-200+	2.53	5.01	0.019	3.5	2.03	3.190	0.138	0.110	0.111	0.073	2.380	0.0196

Table 14: AC4 variety results

S/N	Sample code	EC (µs)	pH	TN (%)	OM %	OC %	CEC me/100g	Ca me/100g	K me/100g	Mg me/100g	Na me/100g	P mg/kg	P me/100g
1	B1/AC4/T1/50	5.09	4.62	0.082	1.866	1.082	4.239	0.108	0.107	0.101	0.074	3.247	0.027
2	B1/AC4/T2/50	2.61	3.5	0.219	1.78	1.032	3.632	0.097	0.049	0.087	0.069	1.179	0.010
3	B1/AC4/T3/50	1.67	4.09	0.093	1.604	0.930	3.331	0.161	0.081	0.121	0.072	3.114	0.026
4	B1/AC4/T2/20	4.75	4.75	0.071	1.874	1.087	3.742	0.118	0.063	0.090	0.075	4.182	0.034
5	B1/AC4/T1/20	3.95	4.47	0.070	0.884	0.513	3.589	0.102	0.077	0.115	0.037	3.014	0.025
6	B1/AC4/T3/20	3.34	5.08	0.043	1.608	0.933	4.227	0.150	0.065	0.100	0.060	3.414	0.028
7	B2/AC4/T1/20	4.04	4.96	0.010	1.794	1.041	3.546	0.099	0.042	0.084	0.072	3.648	0.030
8	B2/AC4/T1/50	1.84	4.96	0.049	1.794	1.041	3.417	0.113	0.056	0.095	0.067	2.013	0.017
9	B2/AC4/T2/20	4.69	5.14	0.062	1.896	1.100	3.472	0.013	0.058	0.105	0.069	2.213	0.018
10	B2/AC4/T2/50	2.19	4.94	0.076	1.594	0.925	3.570	0.115	0.072	0.053	0.268	3.981	0.033
11	B2/AC4/T3/20	3.68	4.73	0.040	1.816	1.053	2.840	0.117	0.044	0.091	0.075	4.148	0.034
12	B2/AC4/T3/50	1.67	4.87	0.305	2.334	1.354	3.368	0.134	0.054	0.098	0.157	1.513	0.012
13	B3/AC4/T1/20	8.35	5.29	0.022	2.2	1.276	6.540	0.020	0.163	0.119	0.204	1.513	0.012
14	B3/AC4/T1/50	2.48	4.75	0.015	2.062	1.196	4.613	0.120	0.089	0.100	0.072	4.015	0.033
15	B3/AC4/T2/20	4.33	4.52	0.032	2.222	1.289	5.208	0.018	0.114	0.105	0.022	2.280	0.019
16	B3/AC4/T2/50	1.39	5.39	0.035	1.86	1.079	4.619	0.168	0.065	0.102	0.060	2.480	0.020
17	B3/AC4/T3/20	1.86	5.18	0.032	1.758	1.020	3.840	0.017	0.095	0.103	0.218	1.680	0.014

18	B3/AC4/T3/50	1.7	5.13	0.057	2.02	1.172	4.748	0.015	0.106	0.111	0.061	1.913	0.016
19	B4/AC4/T1/20	4.72	4.98	0.035	1.768	1.025	4.724	0.023	0.100	0.120	0.211	2.547	0.021
20	B4/AC4/T1/50	1.31	4.86	0.010	2.216	1.285	6.337	0.015	0.093	0.110	0.065	2.480	0.020
21	B4/AC4/T2/20	2.5	4.66	0.103	1.81	1.050	2.184	0.016	0.083	0.111	0.196	3.147	0.026
22	B4/AC4/T2/50	1.42	4.81	0.046	2.234	1.296	2.889	0.013	0.089	0.109	0.073	1.413	0.012
23	B4/AC4/T3/20	4.89	4.92	0.023	2.216	1.285	3.172	0.022	0.102	0.109	0.163	2.447	0.020
24	B4/AC4/T3/50	2.01	4.57	0.01073	2.078	1.205	2.558	0.014	0.110	0.105	0.068	2.013	0.017

Table 15: AZA2 Variety results

S/N	Sample code	EC µs	pH	TN %	OM %	OC %	CEC me/100g	Ca me/100g	K me/100g	Mg me/100g	Na me/100g	P mg/kg	P me/100g
1	B1/AZA2/T1/20	4.4	5.68	0.048	1.778	1.031	10.446	0.170	0.090	0.119	0.269	2.947	0.024
2	B1/AZA2/T1/50	1.91	5.43	0.061	2.184	1.267	7.552	0.137	0.081	0.103	0.068	2.680	0.022
3	B1/AZA2/T2/20	4.24	5.44	0.087	1.446	0.839	2.730	0.087	0.059	0.089	0.070	2.714	0.022
4	B1/AZA2/T2/50	2.31	5.04	0.054	1.578	0.915	3.644	0.113	0.079	0.098	0.069	3.981	0.033
5	B1/AZA2/T3/20	3.07	5.07	0.021	1.72	0.998	4.123	0.106	0.059	0.099	0.269	4.015	0.033
6	B1/AZA2/T3/50	1.63	4.81	0.033	1.81	1.050	3.067	0.094	0.061	0.101	0.072	1.980	0.016
7	B2/AZA2/T1/20	6.39	4.65	0.091	2.38	1.380	4.073	0.017	0.077	0.110	0.038	1.579	0.013
8	B2/AZA2/T1/50	2.31	4.43	0.033	2.032	1.179	2.233	0.120	0.079	0.100	0.266	1.246	0.010
9	B2/AZA2/T2/20	2.59	4.62	0.039	2.238	1.298	3.577	0.164	0.070	0.100	0.164	3.881	0.032

10	B2/AZA2/T2/50	1.68	4.59	0.017	3.78	2.192	3.374	0.126	0.085	0.103	0.062	1.546	0.013
11	B2/AZA2/T3/20	3.22	5.05	0.029	1.678	0.973	4.331	0.016	0.096	0.115	0.267	1.112	0.009
12	B2/AZA2/T3/50	1.8	4.74	0.017	1.844	1.070	3.687	0.155	0.105	0.106	0.068	1.946	0.016
13	B3/AZA2/T1/20	3.36	6.1	0.030	1.868	1.083	4.632	0.017	0.128	0.088	0.269	1.446	0.012
14	B3/AZA2/T1/50	2	4.99	0.009	1.944	1.128	3.098	0.125	0.128	0.116	0.074	2.013	0.017
15	B3/AZA2/T2/20	3.92	5.39	0.010	1.768	1.025	4.386	0.020	0.093	0.112	0.264	2.247	0.018
16	B3/AZA2/T2/50	1.61	5.01	0.020	1.874	1.087	5.411	0.014	0.092	0.116	0.088	3.081	0.025
17	B3/AZA2/T3/20	4.36	4.55	0.036	2.096	1.216	5.104	0.018	0.109	0.117	0.261	3.614	0.030
18	B3/AZA2/T3/50	1.47	4.36	0.024	2.248	1.304	4.687	0.148	0.114	0.117	0.066	5.216	0.043
19	B4/AZA2/T1/20	2.97	4.92	0.045	1.878	1.089	2.583	0.017	0.103	0.105	0.099	3.047	0.025
20	B4/AZA2/T1/50	1.48	4.58	0.023	1.972	1.144	3.123	0.116	0.096	0.106	0.144	2.113	0.017
21	B4/AZA2/T2/20	3.66	4.91	0.010	2.118	1.228	3.012	0.021	0.109	0.099	0.083	2.880	0.024
22	B4/AZA2/T2/50	2.17	4.43	0.006	2.4	1.392	2.871	0.176	0.098	0.196	0.081	2.180	0.018
23	B4/AZA2/T3/20	2.45	4.89	0.037	1.998	1.159	3.730	0.131	0.093	0.212	0.077	1.346	0.011
24	B4/AZA2/T3/50	1.64	4.85	0.037	2.042	1.184	3.656	0.016	0.100	0.198	0.085	4.849	0.040

Table 16: Sample results for (0-20cm)

S/N	Sample code	EC µs	pH	TN %	OM %	OC %	CEC me/100g	Ca me/100g	K me/100g	Mg me/100g	Na me/100g	P mg/kg	P me/100g
1	B1/AC4/T2/20	4.75	4.75	0.071	1.874	1.087	3.742	0.118	0.063	0.090	0.075	4.182	0.034
2	B1/AC4/T1/20	3.95	4.47	0.070	0.884	0.513	3.589	0.102	0.077	0.115	0.037	3.014	0.025
3	B1/AC4/T3/20	3.34	5.08	0.043	1.608	0.933	4.227	0.150	0.065	0.100	0.060	3.414	0.028
4	B1/AZA2/T1/20	4.4	5.68	0.048	1.778	1.031	10.446	0.170	0.090	0.119	0.269	2.947	0.024
5	B1/AZA2/T2/20	4.24	5.44	0.087	1.446	0.839	2.730	0.087	0.059	0.089	0.070	2.714	0.022
6	B1/AZA2/T3/20	3.07	5.07	0.021	1.72	0.998	4.123	0.106	0.059	0.099	0.269	4.015	0.033
7	B2/AC4/T1/20	4.04	4.96	0.010	1.794	1.041	3.546	0.099	0.042	0.084	0.072	3.648	0.030
8	B2/AC4/T2/20	4.69	5.14	0.062	1.896	1.100	3.472	0.013	0.058	0.105	0.069	2.213	0.018
9	B2/AC4/T3/20	3.68	4.73	0.040	1.816	1.053	2.840	0.117	0.044	0.091	0.075	4.148	0.034
10	B2/AZA2/T1/20	6.39	4.65	0.091	2.38	1.380	4.073	0.017	0.077	0.110	0.038	1.579	0.013
1	B2/AZA2/T2/20	2.59	4.62	0.039	2.238	1.298	3.577	0.164	0.070	0.100	0.164	3.881	0.032
12	B2/AZA2/T3/20	3.22	5.05	0.029	1.678	0.973	4.331	0.016	0.096	0.115	0.267	1.112	0.009
13	B3/AC4/T1/20	8.35	5.29	0.022	2.2	1.276	6.540	0.020	0.163	0.119	0.204	1.513	0.012
14	B3/AC4/T2/20	4.33	4.52	0.032	2.222	1.289	5.208	0.018	0.114	0.105	0.022	2.280	0.019
15	B3/AC4/T3/20	1.86	5.18	0.032	1.758	1.020	3.840	0.017	0.095	0.103	0.218	1.680	0.014
16	B3/AZA2/T1/20	3.36	6.1	0.030	1.868	1.083	4.632	0.017	0.128	0.088	0.269	1.446	0.012
17	B3/AZA2/T2/20	3.92	5.39	0.010	1.768	1.025	4.386	0.020	0.093	0.112	0.264	2.247	0.018

18	B3/AZA2/T3/20	4.36	4.55	0.036	2.096	1.216	5.104	0.018	0.109	0.117	0.261	3.614	0.030
19	B4/AC4/T1/20	4.72	4.98	0.035	1.768	1.025	4.724	0.023	0.100	0.120	0.211	2.547	0.021
20	B4/AC4/T2/20	2.5	4.66	0.103	1.81	1.050	2.184	0.016	0.083	0.111	0.196	3.147	0.026
21	B4/AC4/T3/20	4.89	4.92	0.023	2.216	1.285	3.172	0.022	0.102	0.109	0.163	2.447	0.020
22	B4/AZA2/T1/20	2.97	4.92	0.045	1.878	1.089	2.583	0.017	0.103	0.105	0.099	3.047	0.025
23	B4/AZA2/T2/20	3.66	4.91	0.010	2.118	1.228	3.012	0.021	0.109	0.099	0.083	2.880	0.024
24	B4/AZA2/T3/20	2.45	4.89	0.037	1.998	1.159	3.730	0.131	0.093	0.212	0.077	1.346	0.011

Table 17: Samples results for (20-50 cm)

S/N	Sample code	EC µs	pH	TN %	OM %	OC %	CEC me/100g	Ca me/100g	K me/100g	Mg me/100g	Na me/100g	P mg/kg	P me/100g
1	B1/AC4/T1/50	5.09	4.62	0.082	1.866	1.082	4.239	0.108	0.107	0.101	0.074	3.247	0.027
2	B1/AC4/T2/50	2.61	3.5	0.219	1.78	1.032	3.632	0.097	0.049	0.087	0.069	1.179	0.010
3	B1/AC4/T3/50	1.67	4.09	0.093	1.604	0.930	3.331	0.161	0.081	0.121	0.072	3.114	0.026
4	B1/AZA2/T1/50	1.91	5.43	0.061	2.184	1.267	7.552	0.137	0.081	0.103	0.068	2.680	0.022
5	B1/AZA2/T2/50	2.31	5.04	0.054	1.578	0.915	3.644	0.113	0.079	0.098	0.069	3.981	0.033
6	B1/AZA2/T3/50	1.63	4.81	0.033	1.81	1.050	3.067	0.094	0.061	0.101	0.072	1.980	0.016
7	B2/AC4/T1/50	1.84	4.96	0.049	1.794	1.041	3.417	0.113	0.056	0.095	0.067	2.013	0.017
8	B2/AC4/T2/50	2.19	4.94	0.076	1.594	0.925	3.570	0.115	0.072	0.053	0.268	3.981	0.033
9	B2/AC4/T3/50	1.67	4.87	0.305	2.334	1.354	3.368	0.134	0.054	0.098	0.157	1.513	0.012

10	B2/AZA2/T1/50	2.31	4.43	0.033	2.032	1.179	2.233	0.120	0.079	0.100	0.266	1.246	0.010
11	B2/AZA2/T2/50	1.68	4.59	0.017	3.78	2.192	3.374	0.126	0.085	0.103	0.062	1.546	0.013
12	B2/AZA2/T3/50	1.8	4.74	0.017	1.844	1.070	3.687	0.155	0.105	0.106	0.068	1.946	0.016
13	B3/AC4/T1/50	2.48	4.75	0.015	2.062	1.196	4.613	0.120	0.089	0.100	0.072	4.015	0.033
14	B3/AC4/T2/50	1.39	5.39	0.035	1.86	1.079	4.619	0.168	0.065	0.102	0.060	2.480	0.020
15	B3/AC4/T3/50	1.7	5.13	0.057	2.02	1.172	4.748	0.015	0.106	0.111	0.061	1.913	0.016
16	B3/AZA2/T1/50	2	4.99	0.009	1.944	1.128	3.098	0.125	0.128	0.116	0.074	2.013	0.017
17	B3/AZA2/T2/50	1.61	5.01	0.020	1.874	1.087	5.411	0.014	0.092	0.116	0.088	3.081	0.025
18	B3/AZA2/T3/50	1.47	4.36	0.024	2.248	1.304	4.687	0.148	0.114	0.117	0.066	5.216	0.043
19	B4/AC4/T1/50	1.31	4.86	0.010	2.216	1.285	6.337	0.015	0.093	0.110	0.065	2.480	0.020
20	B4/AC4/T2/50	1.42	4.81	0.046	2.234	1.296	2.889	0.013	0.089	0.109	0.073	1.413	0.012
21	B4/AC4/T3/50	2.01	4.57	0.011	2.078	1.205	2.558	0.014	0.110	0.105	0.068	2.013	0.017
22	B4/AZA2/T1/50	1.48	4.58	0.023	1.972	1.144	3.123	0.116	0.096	0.106	0.144	2.113	0.017
23	B4/AZA2/T2/50	2.17	4.43	0.006	2.4	1.392	2.871	0.176	0.098	0.196	0.081	2.180	0.018
24	B4/AZA2/T3/50	1.64	4.85	0.037	2.042	1.184	3.656	0.016	0.100	0.198	0.085	4.849	0.040