LAND CAPABILITY CLASSIFICATION OF THE NATIONAL CENTRE FOR AGRICULTURAL MECHANIZATION (NCAM) FARMLAND

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ABSTRACT
Land capability is the ability of a piece of land to sustainably support the growth of Agricultural crop without damage to the soil. NCAM farmland that has been used for crop production measuring 14 hectares was divided into 8 plots based on their location and accessibility. Samples were taken from each plot to determine the soil physical properties such as textural class, bulk density, moisture content and determination of the chemical properties of the soils, such as electrical conductivity, pH, organic matter content, nitrogen, phosphorus and potassium were carried out for all samples. The results of macro nutrients like soil nitrogen fell below 1% for all the plots, soil potassium was less than 50mg/kg as recommended by FAO and the soil phosphorous fell between 25.12 to 32.38 mg/kg and pH ranges between 7.00 to 8.30. The results showed the capacity of the soil in each plot to sustain a particular agricultural crop production in a sustainable way with minimal cost of production.

Keyword: Land capability, crop production, soil properties, production cost

1. INTRODUCTION
Agriculture has been identified as a strategic sector that would address the multiple challenges of achieving a broad based objective of economic growth, creating wealth and employment, reducing poverty, and attaining national food security as well as putting Nigeria among the 20 world leading economies by the year 2020. The 2006 population census figure for Nigeria was about 150 million people. This is expected to increase to about 220 million by the year 2025 (Musa, 2000). Musa (2001) further postulated an increase in food production from 0.26 million tons/ha to 0.9 million tons/ha in 2025.

The need for increased production has fostered ecologically unsustainable agricultural intensification in many places, leading in particular to soil degradation. Declining Sub-Saharan Africa agricultural productivity is both a cause and a consequence of the deterioration of soil and water resources. One of the objectives of the Millennium Development Goals is to reduce hunger and poverty by half, by the year 2015, and the national food security programme of the present administration is aimed at achieving this objective. Nigeria could be said to be majorly an agrarian society and this has continued to be so because agriculture is still the largest employer of labour. About 82 million hectares out of Nigeria's total land area of about 91 million hectares are arable, (FMA, 2001).

Increased land productivity (greater output/unit of land) generally depends on the application of higher technology and a higher level of knowledge and management ability. Agricultural mechanization is an instrument of farm management and as such changes in mechanization level can have a multiplier effect on output per unit of land. Agricultural mechanization has now been accepted as the most crucial input not only to increase agricultural productivity and promote industrialization of the rural sector but also to promote the overall economic development of nations.

Plants require at least 16 elements for normal growth and for completion of their life cycle. Those used in the largest amounts, carbon, hydrogen and oxygen, are non-mineral elements supplied by air and water. The other 13 elements are taken up by plants only in mineral form from the soil or must be added as fertilizers. Plants need relatively large amounts of nitrogen, phosphorus, and potassium. These nutrients are referred to as primary nutrients, and are the ones most frequently supplied to plants in fertilizers. The three secondary elements, calcium, magnesium, and sulphur, are required in smaller amounts than the primary nutrients. Calcium and magnesium are usually supplied with liming materials, and sulfur with fertilizer materials. Contaminants in rainfall also supply 11.35 to 22.70 Kilograms of nitrogen and sulfur per hectare each year, depending on local air quality (www.soil.ncsu.edu/.../nutrient%20management%20for%20CCA.pdf).

Farouque and Tekeya (2008) observed that the most pressing problem for Bangladesh agriculture was the state of gradual decreasing of soil fertility, stagnating crop yields and declining productivity in a range of food crops.

A similar study carried out by Hasan and Allam (2006) in Bangladesh showed that about 5.6 million ha of Bangladesh's land is deficient in phosphorus, 7.5 million ha are deficient in potassium and 8.7 million ha are deficient in sulfur for the production of upland crops. They further reported incidence of zinc deficiency in about 1.74 million ha of Bangladesh's land and that boron deficiencies are now being noticed; all these are as a result of the major cultivable crops of Bangladesh removing huge amount of nutrient elements from soil.

The technique which allows determination of the most suitable use for any area of land is called land classification. Land capability classification has been defined in different fields to meet targeted objectives, but for the purpose of this work, land capability is referred to as categorization of land according to its capability for optimum agricultural production with the damage to the land reduced to the barest minimum.

According to Onyekwere et al. (2008), African Sub-Saharan region is characterized by chronic food deficit as the net growth in the global population between now and 2050 will occur in the cities of lower income countries, leading to an increase in urbanization (FAO and WWC, 2015). He went further to enumerate some of the factors responsible for the slow pace of food production; this includes vagaries of weather, notably unavailability and uneven monthly distribution of rainfall (Farmer and Wigley, 1985), unfavourable soil conditions such as low effective cat-ion exchange capacity (CEC), low phosphorus and potassium reserves, rapidly declining organic matter and proneness to compaction (Lal, 1993).

To satisfy the food demand and ensure sustainable food production in the area, agricultural production needs to be increased by 2.3% annually over the next decade in order to even maintain the currently substandard national level (Pendleton and Lawson, 1985). The implication of this is that there is a great need for larger agricultural expansion and intensification. Unfortunately the potential for intensification of crop production in agricultural land is fast declining; declining soil fertility being a major factor in the decline (Onyekwere et al. 2008).

Farmers are often advised to use chemical fertilizers for improving soil fertility. However, owing to its unavailability and unaffordability to resource poor farmers as well as its damaging effect on the soil and the environment, an affordable, ecologically stable and sound fertility maintenance measures need to be adopted by farmers for increased crop production. Since soil nutrients are the main contributors to crop production, it becomes imperative that the nutrient status of soils be determined and therefore categorized to support commonly produced crops.

Studies have shown that continuous use of land for crop production without adoption of effective soil conservation techniques often leads to soil degradation, hence reduced crop production over time. Soil degradation was defined by UNEP (1982) as the decline in soil quality as a result of its misuse by humans. Soil degradation is also an outcome of depletive human activities and their interaction with natural environments (Lal and Stewart, 1990). According to Ahaneku (1997), there are three major types of soil degradation; physical chemical and biological. Physical degradation refers to the deterioration of the physical properties of the soil; chemical degradation refers to depletion of soil fertility status through leaching, erosion or crop removal, while biological degradation refers to loss of soil organic matter content.

The basics of balanced fertilization are governed by Liebig's law of the minimum (discussed in Chapter 3). Formerly, it was rightly concluded that, on many soils, the application of N without simultaneous supplies of phosphate and K made little sense. Today, in view of multiple nutrient deficiencies and increasing costs of crop production, fertilization with N or NPK without ensuring adequate supplies of all other limiting nutrients (S, Zn, B, etc.) makes little sense and, in fact, becomes counterproductive by reducing the efficiency of the nutrients that are applied. Therefore, in view of the widespread occurrence of other nutrient deficiencies, the scope and content of balanced fertilization itself has changed. It now includes the deliberate application of all such nutrients that the soil cannot supply in adequate amounts for optimal crop yield. There is no fixed recipe for balanced fertilization for a given soil or crop. Its content is crop and site specific, hence the growing emphasis on Site Specific Nutrient Management (SSNM).

The goal of optimal plant nutrition is to ensure that crop plants have access to adequate amounts of all plant nutrients required for high yield. The nutrients have to be present in the soil or provided through suitable sources in adequate amounts and forms usable by plants. The soil water should be able to deliver these nutrients to the roots at sufficiently high rates that can support the rate of absorption, keeping in view the differential demand at various stages of plant growth. Optimal plant nutrition must ensure that there are no nutrient deficiencies or toxicities and that the maximum possible synergism takes place between the nutrients and other production inputs. The ideal state of optimal plant nutrition may not be easy to achieve in open fields. However, it is possible to come close to it by basing nutrient application on the soil fertility status (soil test) (FAO, 1996).

Crop production yield from NCAM farmland over the years had been dwindling, oftentimes; it is sustained by using lots of fertilizers, costing enormously. Therefore, this project will assist in ensuring sustainability of land fertility and productivity, also reducing production cost to a large extent. Adequate Soil Conservation management can also be ensured by a good soil nutrient management emanating from a study as this.

The objective of this study is to determine the Physicochemical characteristics of NCAM land used for annual crop production so as to guide the farmers on which crop can thrive on each plot with minimum cost of production with less damage to the soil structure.

2. METHODOLOGY

Reconnaissance survey of NCAM farm plots under cultivation was carried out; subsequently, measurement of each plot was be carried out according to the types of crop planted on each. Table 1 shows the NCAM farmland divided into plots according to their location. Three samples were taken from each of the plots for determination of some soil physical properties such as (i) Particle size determination (ii) Field capacity and (iii) Soil bulk density. Determination of the chemical properties of the soils, such as (i) Electrical conductivity, (ii) Soil pH, (iii) Soil organic matter content, (iv) Soil Nitrogen, (v) Soil Phosphorus and (vi) Soil Potassium were carried out for all samples. Parameters such as particle density was determined using sieve analysis. The soil pH was determined using a glass electrode pH meter in a 1:1 soil to water ratio. Organic matter was determined by the wet oxidation method (Nelson and Sommers, 1982), while exchangeable cat-ion was extracted with normal neutral ammonium acetate with sodium and potassium in the extract analyzed by the flame photometry method; calcium and magnesium were determined by the benzoate titration method. Available phosphorus was determined using the Bray method (Bray and Kantz, 1945). The Macro-Kjeldahl method was employed in the total Nitrogen determination (Black, 1965).

Table 1. Field measurement of NCAM farmland

PLOT NO.	PLOT SIZE (Ha)	LOCATION
PLOT 1	1.4296	Beside Maintenance Block
PLOT 2	0.6533	Opposite Plot 1
PLOT 3	1.0405	Back of Former Admin
PLOT 4	1.1668	Next to Road to ARMTI
PLOT 5	1.353	NIFAP PLOT
PLOT 6	0.5415	Next to NIFAP Plot
PLOT 7	3.1031	Cassava Mech. Plot to right
PLOT 8	4.7512	Cassava Mech. Plot to left
TOTAL HECTERAGE	**14.039**	

3. RESULTS

Results of the analysis carried out showed that the textural class of the soil is the same in all the fields sampled for this research work , i.e. loamy sand, with sand having the highest percentage of the aggregates using USDA classification of soil texture classes according to proportions of sand, silt and clay as shown in Table 1.

Table 2. Textural Classification of soil

	Sand (%)	Silt (%)	Clay (%)	Textural Class
Plot 1	82.96	16.87	0.17	Loamy sand
Plot 2	85.55	14.43	0.02	Loamy sand
Plot 3	84.05	15.49	0.00	Loamy sand
Plot 4	86.30	13.58	0.12	Loamy sand
Plot 5	89.00	10.25	0.75	Loamy sand
Plot 6	84.46	15.40	0.14	Loamy sand
Plot 7	87.14	12.74	0.13	Loamy sand
Plot 8	87.64	11.40	0.96	Loamy sand

The result on Table 3 shows the soil pH and the soil chemical compositions in the different plots (1~8) considered for this study. The soil pH-value from plot 1 to plot 8, are as follows; 7.10, 7.00, 6.93, 6.50, 6.47, 8.30, 7.17 and 6.30, respectively. According to soil pH classification by Brady and Well (1996), the soil sampled based on plots fall under the following pH indicators; the soil sampled from plot 2 alone has a neutral pH value, while plots 2 and 7 are very slightly alkaline. On the other hand, plots 3, 4, 5 and 8 are slightly acidic, while plot 5 only can be considered as very slightly acidic, with the exception of plot 6 which is a medium alkaline soil. For the soil chemical compositions, the EC-values (EC) from plot 1~8 are as follows; 0.03, 0.03, 0.06, 0.03, 0.02, 0.03, 0.05 and 0.06 µS cm^{-I} respectively. These values falls between the EC-value for a normal loamy sandy soil, because according to Smith and Doran (1996) the EC-values for normal loamy sandy soil ranges between 0~1.2 µS cm^{-I}. Nevertheless, for the soil moisture content (MC), the plot 1 had the highest value of 14.23 %, followed by plot 6 with MC value of 12.23 %. MC value for plot 7 was also fair with 11.69 % MC, while plots 2, 3 and 4 have closely related MC values, with values 9.35, 9.10 and 9.34 % respectively. Plots 8 and 5 have the lowest MC values of 8.45 and 7.60 %, respectively. Evaluation of moisture content from the various plots revealed that they were within the limit of a normal Sandy loam soil, (Taylor and Ashcroft, 1972). The Bulk density (BD) from the various plots seemed to be similar from plot 1~8 with values as 1.40, 1.37, 1.28, 1.43. 1.21, 1.33, 1.43 and 1.21g cm,$^{-3}$ respectively. On the other hand, the Organic matter (OM) varied from plot to plot and the OM for plot 4 has the highest value of 4.26 % while the OM from plot 1 and 3 were relatively high with values as 3.56 and 3.29 %, respectively, but the OM from plots 6, 2, 5 and 7 were closely related (2.90, 2.67, 2.49 and 2.27 %) and they are lower when compared to plots 1 and 3. Plot 8 has the lowest value of OM of 1.94 % compared to other plots. The soil primary nutrients (N, P, K, MgO) composition varies from plot to plot. NH_3-N value for each soil, are all less than 1 %, therefore their values are negligible and can be improved upon by addition of organic/inorganic soil amendment. The soil phosphate value from plots 1, 2, 3, 4, 5, 6 and 8 are 29.52, 26.99, 32.21, 25.12, 25.46, 29.77 and 32.38 mg kg^{-1}, respectively. According to FAO (1980), all seven are classified as soil with very high fertility of phosphate, while plot 7 with phosphate content 23.67 mg kg-1 fall in the category of soil with high fertility of phosphate. For the soil potassium analysed from all the plots sampled, the potassium concentrations are 34.67, 30.67, 33.33, 30.67, 32.00, 36.00, 30.67 and 28.00 mg kg,$^{-1}$ respectively. According to the soil fertility classification (FAO, 1980), they all fall under the same category of soil with very low fertility of soil potassium-oxide (< 50 mg kg^{-1}), while the soil magnesium-oxide analysed from all the plots sampled, the amount of magnesium from plots 1~8 are 13.20, 15.76, 16.60, 12.35, 15.83, 17.71, 12.53 and 14.04 mg kg^{-1}, respectively. They all fall, under the same category of soil with very low fertility of soil magnesium-oxide (< 20 mg kg^{-1}) according to the soil fertility classification (FAO, 1980). For calcium oxide (CaO) analysed from all the plots sampled, the amount of calcium from plots 1~8 are 54.67, 46.67, 64.0, 49.33, 61.33, 80.0, 69.33 and 66.67 mg kg^{-1}, respectively. Although, the amount of calcium in all the plots are in the range value for tropical soils climate (Brady, 1974). While for iron (Fe), the result from the chemical analysis from all the plots (1~8) are; 112.10, 110.32, 215.14, 221.71, 175.20, 142.48, 128.46 and 140.60 mg kg^{-1} respectively. Also, for manganese (Mn), analysed from all the plots sampled, the amount of calcium from plot 1~8 are 1.31, 1.42, 0.70, 0.65, 0.81, 1.06, 0.92 and 0.35 mg kg^{-1} respectively. The amount of Fe and Mn, should not be worrisome, because they are micronutrient for plant benefit, and most chemical fertilizer contain considerable amount of both mineral nutrient for plant usage.

Table 3: Mean value of the soil chemical compositions at different locations in the NCAM farm land

Location (Plot)	pH	EC µS cm^{-1}	MC %	BD g cm^{-3}	OM %	NH_3-N %	P_2O_5 mg kg^{-1}	K_2O mg kg^{-1}	MgO mg kg^{-1}	CaO mg kg^{-1}	Fe^{2+} mg kg^{-1}	MnO mg kg^{-1}
1	7.10	0.04	14.23	1.40	3.56	0.46	29.52	34.67	13.20	54.67	112.10	1.31
2	7.00	0.03	9.35	1.37	2.67	0.63	26.99	30.67	15.76	46.67	110.32	1.42
3	6.93	0.06	9.10	1.28	3.29	0.70	32.21	33.33	16.60	64.00	215.14	0.70
4	6.50	0.03	9.34	1.43	4.26	0.48	25.12	30.67	12.35	49.33	221.71	0.65
5	6.47	0.02	7.60	1.21	2.49	0.28	25.46	32.00	15.83	61.33	175.20	0.81
6	8.30	0.03	12.25	1.33	2.90	0.69	29.77	36.00	17.71	80.00	142.48	1.06
7	7.17	0.05	11.69	1.43	2.27	0.31	23.67	30.67	12.53	69.33	128.46	0.92
8	6.30	0.06	8.45	1.21	1.94	0.60	32.38	28.00	14.04	66.67	140.60	0.35

pH= Acidity or Alkalinity; EC=Electrical Conductivity; MC=Moisture Content; BD=Bulk Density; OM=Organic Matter

Soil nutrients, as well as its availability are important not only as they affects crop plant productivity, but as it determines the potential movement of nutrients outside the boundaries of the crop field, and their impact on air, water resources and native ecosystem. The fertility recommendation of the various plots, due to the results of the soil chemical compositions, can be best explained by the bioavailability of the essential plant nutrients. The bioavailability of these nutrients is most associated with the inherent pH-value of the field (Brady and Well, I996). Plant bioavailability by Peck and Soltanpour (1990), can be defined as the chemical form or forms of an essential plant nutrient in the soil whose variation in amount is reflected in variation with plant growth and yield. Most plants do well on pH-value between 6.0~7.5, but some plants are exceptional. However, this is the pH-value range for the bioavailability of most of the essential nutrients required by crop, for adequate growth and yield. Therefore, from the results above, most of the plots (1, 2, 3, 4, 5, 7 and 8) fall between the pH-value range of 6.0~7.5, except for plot 8, that had a pH-value higher than 7.5. As a result, all the plots, except plot 8, are expected for all their inherent essential nutrients to be available for plant uptake, while for plot 8 being an alkaline soil in nature, all its essential plant nutrient may not be available for plant uptake, even though they are present in the soil (Brady and Weil, I996), so there may be need for the soil (plot 8) to be ameliorated for agricultural benefit. In this regard, organic fertilizer with a cation charge, for example ammonium (NH_4^+) can be utilized to reduce the soil pH-value. Many studies had been reported using the concept of rhizosphere acidification, which occurs as a consequence of N_2 fixation from either legume or ammonium fertilizer supply, can lead to pH decrease of about 2pH units (Gahoonia et al., 1992; Li et al., 2008). Therefore, this concept will ameliorate the bioavailability of the essential plant nutrient present in the soil. On the other hand, some other properties of the field, such as moisture content (MC), bulk density (BD), and salinity (EC) affected the rate of Phosphate mineralization from organic matter (OM) decomposition. OM decomposition and release of Phosphate (P_2O_5) is faster in the tropical climate and slower in temperate climate. P_2O_5 is released faster also, when soil is well aerated (good BD), and much slower on saturated wet soils. Nevertheless, soils with inherent pH values between 6 and 7.5 are ideal for P_2O_5-availability, while pH-value below 5.5, and between 7.5~8.5 limits P_2O_5-availability to plants due to fixation by aluminum (Al^{3+}), iron (Fe^{2+}), or calcium (Ca^{2+}), these had been reported by the California Fertilizer Association, 1995. Phosphorus does not readily leach out of the root zone, but the potential for P_2O_5-loss is mainly associated with erosion and runoff. Therefore, the plots that are most prone to erosion, runoff, or are in close proximity to streams, lakes and other water bodies needs to be closely managed to avoid P_2O_5 loss. Additionally, Fe deficiency is mostly triggered by the high availability of Mn or high pH soil as mentioned, though not all crop can be affected, but crops like Sorghum, Maize, Alfalfa, together with tree crops etc. are likely to be affected. For the potassium, the amount of potassium from all the plots were in the category of soil with very low fertility of soil potassium-oxide (they are < 50 mg kg^{-1}) according to the soil fertility classification (FAO, 1980). Therefore, the eight (8) plots soil potassium concentration needed to be ameliorated. These can be done using organic/inorganic fertilizers, organic fertilizer like coconut peat, oil palm ash (James et al., 2016) can be used to improve the soil potassium concentration. Also, inorganic fertilizer can be used solely, such as sulphate of potash (SOP) or it can be incorporated with the inorganic fertilizer for potassium amelioration. For, Magnesium amount from all the plots, were in the category of soil with very low fertility of soil magnesium-oxide (they are < 20 mg kg^{-1}) according to the soil fertility classification (FAO, 1980); this can be ameliorated using organic/inorganic fertilizers, organic fertilizer like animal manure can be used to improve the soil magnesium concentration. Also, inorganic fertilizer can be used solely, such as Epsom salts, and sulphate of potash magnesia or it can be incorporated with the inorganic fertilizer for magnesium amelioration. Although, the amount of calcium might not be necessary ameliorated because they are in the range value for tropical soils climate (Brady, 1974).

Magnesium is indispensable in the processes of protein hydrolysis in plant vegetative organs as well as for the transfer of assimilation products from leaves to ears. This nutrient takes part in photosynthesis (prolongs the stage of green leaves) and transportation of proteins from plant vegetative organs to seeds or kernels (Cakmak, Kirkby 2008). The yield forming effect of magnesium is particularly evident under the conditions of insufficient supply of nitrogen to plants (Grzebisz 2013). Calcium regulates osmotic and ionic processes in cell membranes, and magnesium works as a cofactor in enzymatic reactions (White, Broadley 2003).

The effects of calcium and magnesium deficiency are evident in plants growing on excessively acidic soils, with a low Ca content caused by the leaching of Ca2+ cations or with low cation-exchange capacity (CEC), as well as under the conditions of aluminium toxicity to the plant root system (Rengel, Elliot 1992, Ryan et al. 1994).

Table 4: Soil pH classification and nutrient availability

pH	**Classification**	**Available Nutrient**
4.0-5.5	Strongly acidic	Fe, Mn, B, Cu and Zinc
5.5-6.0	Medium acidic	Fe, Mn, B, Cu and Zinc
6.0-6.5	Slightly acidic	N, P, K, S, Ca and Mg
6.5-7.0	Very Slightly acidic	N, P, K, S, Ca and Mg
7.0-7.5	Very Slightly alkaline	N, P, K, S, Ca and Mg
7.5-8.0	Slightly alkaline	N, P, K, S, Ca and Mg
8.0-8.5	Medium alkaline	Mo
8.5-10	Strongly alkaline	Mo

Source: Brady and Well (1996)

The soil pH of all the sampled plots varied from 6.0 to 8.4. With reference to Table 1 above, pH results for Plot 1 showed that the soil is very slightly alkaline with the possibility of availability of nutrients as N, P, K, S, Ca and Mg ions. The plot has an average pH of 7.1. Plot 2 showed a pH range from 7.2 for 0-7 cm depth to 6.9 for depths 7-14 an 14-21, respectively, but with an average pH of 7.0; this plot fall in the class of very slightly acidic soil, also with the possibility of availability of nutrients such as N, P, K,S, Ca and Mg ions.

Plot 3 showed a slight pH variation of 7.1 for 0-7 cm depth and 6.9 to 6.8 for depths 7-14 and 14-21 cm depths respectively, but with an average pH of 6.9, it falls in the class of with the possibility of availability nutrients as N, P, K,S, Ca and Mg ions. Plot 4 on the other hand showed a consistence in pH of 6.5 down the soil profile and falls between the classes of very slightly acidic and slightly acidic also with the possibility of nutrients as N, P, K,S, Ca and Mg ions. Plot 5 showed a decrease in pH from 6.6 to 6.4 down the soil profile, but with an average pH of 6.47, meaning it falls in the class of slightly acidic soil with the possibility of availability of such nutrients as N, P, K, S, Ca and Mg ions. In Plot 6, the results showed a moderately alkaline soil with a pH range of 8.2 to 8.4, but with an average pH of 8.3; this plot is in medium alkaline soil class with the possibility of availability of Mo. The pH of the plot 7 soil ranged from 7.0 to 7.3 with an average of 7.2, placing it in the pH class of very slightly alkaline soils with the possibility of availability of N, P, K,S, Ca and Mg ions. Plot 8 has a pH range from 6.0 to 6.5 but with an average of 6.3, placing it in the pH class of slightly acidic soils with the possibility of availability of N, P, K, S, Ca and Mg ions.

Table 5. Soil fertility classification

Soil Fertility Class	AVAILABLE EXTRACTABLE NUTRIENT			EXPECTED RELATIVE YIELD WITHOUT FERT. (%)
	Phosphorus (P) (mg/kg)	Potassium (k) (mg/kg)	Magnesium (Mg) (mg/kg)	
Very Low	< 5	< 50	< 20	< 50
Low	5-9	50-100	20-40	50-80
Medium	10-17	100-195	40-80	80-100
High	18-25	175-300	80-180	100
Very High	> 25	> 300	> 180	100

Source: FAO (1980)

With reference to the above table of fertility classification, soil in plot 1 has phosphorus content ranging between 27.72 mg/kg to 31.51 mg/kg, with an average Phosphorus content of 29.52. This shows that the phosphorus content is quite sufficient to support crop growth, i.e. very high. The same thing goes for plot 2 with phosphorus content ranging from 24.25 to 30.01 mg/kg and an average content of 26.99 mg/kg. Plot 3 has higher Phosphorus than plots 1 and 2 with the Phosphorus content ranging from 28.99 to 35.06 mg/kg of soil. The average Phosphorus content of plot 3 being 32.21 mg/kg; this plot does not have any Phosphorus problem as the Phosphorus content is very high and adequate enough to support plant growth. The Phosphorus content of plot 4 ranged from 21.46 to 29.17 mg/kg with an average 25.12 mg/kg; this with reference to FAO (1980) is also very high in Phosphorus and adequate to support plant growth. Plot 5 has Phosphorus content ranging from 22.75 to 28.17 mg/kg with an average content of 25.49 mg/kg; this also is very high and adequate enough to support growth. In plot 6, the Phosphorus content ranged from 28.38 to 30.83 mg/kg with an average content of 29.77 mg/kg. The fertility class relative to its phosphorus content shows it is very high and adequate for plant growth. The soil of plot 7 showed a range of Phosphorus between 20.98 and 27.00 with an average of 23.67. The FAO standard for fertility shows that with respect to phosphorus, plot 7 falls in the high class, still sufficient enough to support growth while plot 8 contains between 26.18 and 37.02 mg/kg of phosphorus, the average Phosphorus content being 32.38 mg/kg. The results showed that there is no issue with any of the sampled plots with reference to Phosphorus.

The Magnesium content of plot 1 showed a slight variation from 10.88 to 16.28 mg/kg with an average of 13.20 mg/kg. This shows a Magnesium content of less than 20 mg/kg; this, according to the soil fertility standard of FAO (1980) is in the very low class and may not be able to support plant growth adequately. The Magnesium content of plot 2 ranged from 11.40 and increased down the soil profile to 22.04 mg/kg with an average of 15.59 mg/kg; this is also less than 20 mg/kg and therefore too low to support growth adequately. The variation in magnesium content of plot 3 ranged from 16.32 to 20.24, but with an average of 16.6. The soil of this plot also fall in the class of very low and may not support growth adequately. The variation in Magnesium content of the soil in plot 4 ranged from 7.88 in the 0-7 cm depth and increased to 17.16 mg/kg in the 14-21 cm depth; the average Magnesium content being 12.35 mg/kg. This is far too low to the benchmark of 20, therefore in the fertility class of very low. Magnesium content of plot 5 varied from 15.00 to 16.52 mg/kg with an average content of 15.83 mg/kg of soil; this also is in the very low class and may not sufficiently support crop growth. Plot 6 has Magnesium content ranging from 15.12 to 20.00 mg/kg, but with an average of 17.71; this also fall in the class of very low. Magnesium content of Plot 7 varied from 10 to 16.04 with an average of 12.53; in the Very Low class and may be insufficient to support plant growth adequately. The Magnesium content in plot 8 increased down the profile from 8.12 to 20 mg/kg, but with an average of 14.04. The results of the Magnesium content of all the plots fell below the minimum; this may likely have negative implications on the productivity of the plots.

The result of the analysis showed that Potassium level in plot 1remain unchanged at 36 mg/kg for the layers 0-7 and 14-21, respectively but reduced to 32 in the 14-21 soil layer. The average of the three reading is 34.67 mg/kg. Reference to the FAO (1980) fertility standards showed that it is very low (I.e. less than 50); the productivity of this plot may likely be affected by this result. The Potassium content of plot 2 increased down the profile from 28 to 32 but with an average of 30.67; this value is less than the minimum and therefore too low to support substantial productivity. The soil in plot 3 showed a Potassium content decreasing don the soil profile from 36 in the upper layer to 32 mg/kg in the lower level; the average being 33.33 mg/kg; this also is very low and may likely result in low productivity. The Potassium content of plot 4 also reduces from a value of 32 mg/kg in the first two layer of the soil to 28 mg/kg in the last layer; the average Potassium content being 30.67 mg/kg; it also falls in the class of very low. There is consistency down the profile for Potassium content of plot 5; it remained 32 mg/kg in all the layers of the plot, the average also being 32 mg/kg. This average potassium content ranks this plot in the very low class, hence may affect productivity. The analysis results of plot 6 revealed a reduction in the content of Potassium down the profile from 36 mg/kg in the first two layers to 32 mg/kg in the last layer; the average of the three being 34.67. This again is in the class of very low and may affect its productivity. On the contrary, the is an increase down the profile in the Potassium content of plot 7; it increased from 28 mg/kg in the upper 0-7 cm layer to 32 mg/kg in the two lower layers. The average Potassium in this plot is 30.67 mg/kg; it falls in the class of very low in the soil fertility class, hence may affect productivity. Plot 8 showed a consistency in its Potassium content down the profile; its 28 mg/kg all through, therefore the average Potassium is 28 mg/kg. The results in all the plots for Potassium also revealed a very low level of Potassium in all the plots, this may have negative impact on the productivity in all the plots.

4. CONCLUSION

The pH-value of the various plots sampled fall within the range of soil with nutrient availability for plant uptake, except for plot 6. The soils are all classified as a loamy sand soil. While plot 6, needed to be ameliorated by a decrease in soil pH-value to at most 2 pH units.

4.1 Recommendation

The following recommendations are made to ameliorate the effects of highlighted deficiencies, i.e. in Magnesium and Potassium for all the plots

Magnesium Remediation

Natural reserves of Mg are very large, both in salt deposits (MgCl2, MgCO3, etc.) and in mountains consisting of dolomite limestone (CaCO3.MgCO3). There are several commercially available materials of acceptable quality that can be used to provide Mg to soils and plants. There are two major groups of Mg fertilizers, namely, water soluble and water insoluble. Among the soluble fertilizers are magnesium sulphates, with varying degree of hydration, and the magnesium chelates. The sulphates can be used both for soil and foliar application whereas the chelates, such as magnesium ethylenediaminetetra acetic acid (Mg-EDTA), are used mainly for foliar spray. Some sources of Mg are:

(i) magnesium oxide (MgO): contains 42 percent Mg (Mg × 1.66 = MgO)
(ii) magnesite (MgCO3): contains 24–27 percent Mg.s
(iii) dolomitic limestone (MgSO4.CaSO4): contains 3–12 percent Mg.
(iv) magnesium sulphate anhydrous (MgSO4): contains 20 percent Mg
(v) magnesium sulphate monohydrate (MgSO4.H2O): contains 16 percent Mg.
(vi) magnesium sulphate heptahydrate (MgSO4.7H2O): contains 10 percent Mg.
(vii) magnesium chloride (MgCl2.6H2O): contains 12 percent Mg
(viii) potassium magnesium sulphate (K2SO4.2MgSO4): contains 11 percent Mg.

Magnesium sulphate is the most common Mg fertilizer. In anhydrous form, it contains 20 percent Mg. As a hydrated form, MgSO4.7H2O (Epsom salt), it contains10 percent Mg. (FAO, 1996).

Soil Remediation for Potassium Deficiency

Potash fertilizers are predominantly water-soluble salts. For historical reasons, their Potassium concentration is generally still expressed as percent K2O, particularly by the industry, trade and extension. As such, the nutrient K does not exist as K2O in soils, plants or in fertilizers. It is present as the potassium ion K+ in soils or plants and as a chemical compound (KCl, K_2SO_4) in fertilizers.

(i) The first potash fertilizers were ground crude K salts containing 13 percent K_2O.These are still used to some extent for fertilization of grassland in order to supply K and Na.
(ii) Potassium chloride (KCl), also called muriate of potash (MOP), is the most common Potassium fertilizer. It is readily soluble in water and is an effective and cheap source of K for most agricultural crops.
(iii) Potassium sulphate (SOP) is actually a two-nutrient fertilizer containing 50 percent K2O and 18 percent S, both in readily plant available form. It is

costlier than MOP but is particularly suitable for crops that are sensitive to chloride in place of KCl. It has a very low salt index (46.1) as compared with 116.3 in case of MOP on material basis (FAO, 1996).

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