SOIL TESTING GUIDE

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Market-Oriented Agriculture Programme Of the Ministry of Food & Agriculture

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Foreword

Most African countries have long been dependent on agriculture for their development. However, low soil fertility and anthropogenic disturbances such as deforestation and exploitive farming practices have led to poor crop yields that do not augur well for sustainable agriculture. Of particular importance is the problem of low soil fertility which occurs as a result of strong weathering and leaching processes that prevail under a tropical climate. It is therefore important that farmers know the fertility status of their soils in order to correct any nutrient deficiencies before cropping. Soil testing helps farmers to take an informed decision as to what type and rate of fertilisers to apply in order to increase crop yields.

This Manual is intended for farmers in Ghana (primarily producers of fruit crops and maize) as well as their advisors and extension agents. In an attempt to solve the problems of low soil fertility, the Manual provides a guideline to soil sampling and interpretation of soil analytical data. The Manual, it is envisaged, will be handy not only to large-scale commercial farmers but also to peri-urban and small-scale farmers. It is hoped that farmers will find it useful and take interest in testing their soils at known and well-equipped laboratories.

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1. Background

The low crop yield on smallholder farmers' fields in the tropics is attributed to low soil fertility resulting from nutrient poor and highly weathered soils managed with little external inputs. Soil nutrients are lost through crop uptake, soil erosion and leaching. Soil nutrients, on the other hand, are added through mineral fertilisers, organic resources such as manure and plant biomass, rainfall (for Nitrogen) as well as biological fixation (for Nitrogen). Soil fertility evaluation assesses the capacity of individual fields to supply adequate nutrients for specific crops and associated yield and quality objectives. The initial step is to determine the current soil nutrient status.

2. Nutrient deficiencies

Plants, like any other organisms, require some nutrients for their normal growth and development. The deficiency or absence of these nutrients may pose serious defects known as deficiency diseases to the plant. Eighteen elements have been found to be essential for higher plants. All elements are not essential for all plants. The elements are: Carbon (C), Hydrogen (H), Oxygen (O), Nitrogen (N), Phosphorus (P), Potassium (K), Sulphur (S), Magnesium (Mg), Calcium (Ca), Iron (Fe), Manganese (Mn), Zinc (Zn), Copper (Cu), Boron (B), Molybdenum (Mo), Chlorine (Cl), Nickel (Ni) and Cobalt (Co).

According to the law of the "limiting factor", the most deficient nutrient determines the overall yield. Other nutrients cannot compensate for the deficient nutrient. This results in decreased quality and yield.

Carbon (C), Hydrogen (H) and Oxygen (O) are obtained from the atmosphere and water and are not considered mineral elements. The remaining essential elements can be divided into 3 based on average concentrations in plants.

Primary **macronutrients** (**N, P, K**) and secondary macronutrients (**S, Mg, Ca**): These nutrients are needed in large quantities by the plant. Their concentration in plants ranges from 0.2 to 5% or greater. **Micronutrients** (Fe, Mn, Zn, Cu, B, Mo, Cl, Ni, Co): These are required in small quantities for plant growth. Their concentration in plants ranges from 0.1 to 100 ppm (parts per million).

Table 1 shows the essential elements, their functions and deficiency symptoms in plants. Visual identification of nutrient deficiency symptoms can be a practical tool for evaluating the nutrient status of the plant in addition to soil and tissue analysis. However, one needs to differentiate between nutrient deficiency symptoms and plant disease symptoms. In general, if symptoms occur uniformly across the field and do not vary between plants, it is more likely that they are related to nutrient deficiencies rather than to plant disease. In addition, deficiency symptoms develop slower, but disease symptoms faster.

Exercise 1

A. List two macronutrients that are likely to be deficient in your soil:

- ________
- ________

B. List two micronutrients that are likely to be deficient in your soil:

- ________
- ________

Table 1: Important soil nutrients, deficiency symptoms & corrective measures

Nitrogen (N)

Role in plant life:

Protein is made of Nitrogen. It is therefore important for good plant growth.

Deficiency symptoms:

Chlorosis (yellowing of leaves) and stunted growth. Small fruits.

Symptoms first appear:

On ***old*** leaves

Corrective measures:

Apply fertilisers such as

✓ Urea
✓ Ammonium sulphate
✓ Potassium nitrate
✓ Ammonium nitrate

Apply organic materials (compost, manure).

N deficiency in maize

N deficiency in the left palm

Phosphorous (P)

Role in plant life:

Enhances

- ✓ Nitrogen fixation
- ✓ Flowering
- ✓ Fruiting
- ✓ Seed formation
- ✓ Development of lateral roots and fibrous rootlets

Deficiency symptoms:

Plants are stunted and stiff, thin-stemmed and spindly.

Dark foliage, almost bluish-green. Some plants e.g. maize develop purple colour in their leaves and stem.

Delayed maturity, sparse flowering, small fruits and poor germination.

Symptoms first appear:

On ***old*** leaves

Corrective measures:

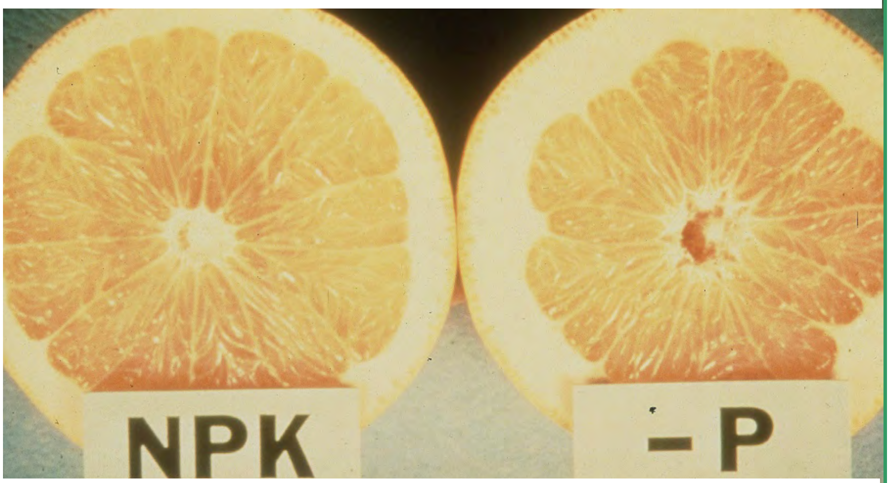
Apply fertilisers such as

- ✓ Triple or Single superphosphate
- ✓ Rock phosphate particularly for tree crops

Apply organic materials such as high-phosphorus animal manure (from chicken and pigs) or compost.

P deficiency in maize

P deficiency in tomatoes



P deficiency in oranges

Potassium (K)

Role in plant life:

Regulates stomata and gives higher drought tolerance.

Resistance to fungal & bacterial infections.

Improves taste as it activates enzymes.

Deficiency symptoms:

Tips and edges of leaves are necrotic (have died).

Small fruit with low acidity and little aroma.

Symptoms first appear:

On ***old*** leaves

Corrective measures:

Apply fertilisers such as

- ✓ Potassium chloride (KCl), but **not for fruits & vegetables**
- ✓ Muriate of potash (K_2O)
- ✓ Potassium sulphate (K_2SO_4), **best for fruits & vegetables**
- ✓ Potassium nitrate (KNO_3)

K deficiency in cocoyam

K deficiency in mango

Calcium (Ca)

Role in plant life:

Strengthens cell wall structure. Promotes proper cell elongation.

Deficiency symptoms:

Small, short and breakable leaves. Curling of leaves. Leaf tip burns.

Blossom end rot in tomatoes.

Symptoms first appear:

On ***young*** leaves

Corrective measures:

- ✓ Lime ($CaCO_3$) which also increases soil pH
- ✓ Gypsum
- ✓ Single superphosphate
- ✓ Calcium nitrate as liquid fertiliser suited for a foliar spray

Ca deficiency in tomatoes (blossom end rot)

Ca deficiency in mango causing "soft-nose breakdown"

Ca deficiency in pineapples: Irregularly shaped margins on new heart leaves resembling the damage caused by chewing insects (from R.G. Weir et al.: Plant Nutrient Disorders, Tropical Fruit and Nut Crops)

Magnesium (Mg)

Role in plant life:

Is a constituent of chlorophyll. Promotes the sugar supply to the growing fruits.

Enhances taste, fruit size and colouration of fruits.

Magnesium is needed to balance the large amounts of Potassium required by pineapples.

Deficiency symptoms:

Interveinal yellowing of older leaves while veins remain green.

Fruits without acidity, low in sugar content and without flavour.

Symptoms first appear:

On ***old*** leaves

Corrective measures:

Apply fertilisers such as

- ✓ Calcareous dolomites
- ✓ Magnesium sulphate as liquid fertiliser suited for a foliar spray

Mg deficiency in a tomato leaf

Mg deficiency in citrus

Mg deficiency in a banana leaf

Sulphur (S)

Role in plant life:

Is a component of some proteins and vitamins.

Essential in the manufacturing of chlorophyll.

Deficiency symptoms:

Spindly, thin stems and leaf stalks.

Light green or yellow (chlorotic) appea-rance.

Symptoms first appear:

On ***young*** leaves

Corrective measures:

Apply

- ✓ Organic materials
- ✓ Calcium sulphate (gypsum)
- ✓ Magnesium sulphate as liquid fertilser (with foliar use)
- ✓ Elemental Sulphur (also a fungicide against phytophtora)

S deficiency in a maize crop

S deficiency in a palm

Boron (B)

Role in plant life:

Promotes cell division, elongation and cell wall strength.

Deficiency symptoms:

Distorted growth. Inhibition of fruit and seed developments. Cracks appear. Fruit may be hollow, hard and lacking in juice.

Symptoms first appear:

On ***young*** leaves

Corrective measures:

Apply Boric acid.

B deficiency in mangoes

Left: B deficiency in pineapples with cracking and cork formation on and between fruitlets

Right: B deficiency in pawpaw which causes flowers to shed and few fruits to set. Those which develop are deformed and often white latex exudes from the skin during fruit growth (from R.G. Weir et al.: Plant Nutrient Disorders, Tropical Fruit and Nut Crops)

Copper (Cu)

Role in plant life:

Essential in several plant enzymes involved in photosynthesis.

Deficiency symptoms:

Mango: Long, tender and “S” shaped branches; leaves with mottles and downward curls; boil-like eruptions on the bark.

Symptoms first appear:

On ***young*** leaves

Corrective measures:

Apply animal manure to prevent Cu deficiency.

Apply copper solutions as foliar fertilisers to treat Cu deficiency.

Cu deficiency in oranges

Cu deficiency in maize

Cu deficiency in pineapples with leaves U-shaped in section (from R.G. Weir et al.: Plant Nutrient Disorders, Tropical Fruit and Nut Crops)

Exercise 2

Look at the three illustrations of plant nutrient deficiency symptoms. State for each case what the deficiency is and what can be done about it.

A.

B.

C.

3. Soil physical properties

Soil texture (sand, silt and clay content) and bulk density (grams of soil per cm^3) influence root development and soil nutrient uptake. Soil texture and structure determine the water holding capacity of soils, e.g. silt loam and clay soils hold more plant available water than sandy soils. Bulk density is a measure of how dense and compacted a soil is. The higher the bulk density the less the pore space, the less oxygen available for root growth and the more difficult it is for the young roots to penetrate the soil. Large root systems increase total nutrient uptake, a key factor for higher crop yields.

Soil management practices that maximise root growth will aim at improving crumb structure and porosity. Such practices include measures to increase the organic matter content of the soil:

1. Recycling of crop residues (especially roots)
2. Composting
3. Green manuring (e.g. with mucuna, cowpeas, crotalaria, pigeon pea)
4. Crop rotation including crops that increase humus in the soil (e.g. grass family)

Such soils will have a better water and nutrient holding capacity. The potential ability of a soil to hold on to the following nutrients: K, Mg, Ca and Na is measured as “CEC” (Cation Exchange Capacity). The higher the CEC the better.

Sun hemp (crotalaria) makes an excellent green manure crop in Southern Ghana. In addition to providing organic mater, it fixes Nitrogen and controls nematodes in the soil.

4. Soil pH

In addition to measuring the nutrients in a soil, it is essential to know the pH of the soil. Soil pH is the measure of the acidity or alkalinity of the soil. It affects plant growth, as it determines the availability of nutrients in the soil.

Soil pH is measured on a scale from 0 to 14, with 7 being neutral. A highly acid soil can have a pH as low as 3, while a highly alkaline soil can be close to pH 10. Most soils in West Africa are acidic with pH levels of often below 5. Plant growth is usually best in a slightly acid soil (pH 5.5 to 6.5).

Figure 1 illustrates the availability of nutrients in relation to the soil pH. The wider the bar the better is the nutrient availability. Be aware that if your soil pH reads **below 5.5** many nutrients such as:

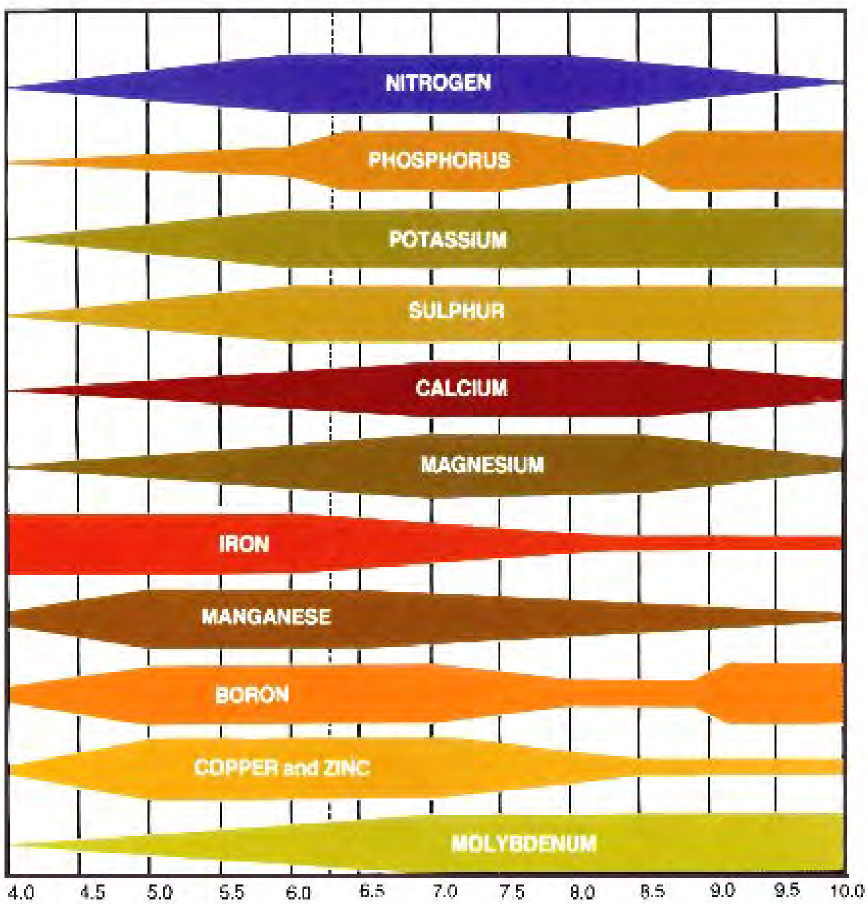
▶ Nitrogen ▶ Phosphorous ▶ Potassium ▶ Magnesium ▶ Molybdenum

can become critically unavailable. If your soil pH reads **below 5.0** nutrients as:

▶ Manganese ▶ Boron ▶ Copper ▶ Zinc become additionally unavailable.

Under such circumstances you have to increase the pH first, since adding of nutrients to the soil will have no effect on plant growth.

Figure 1: Relationship between soil pH and nutrient availability



The measurement of the soil pH is part of a laboratory soil analysis.

A quick method of measuring soil pH in field, however, is using inexpensive **pH indicator strips**. In Ghana they are available from:

PKF Scientific Ltd.
Appiawah House
Spintex Road
P.O.Box NG 380, Nungua, Accra, Ghana

Contact Mr. Emmanuel Kofi Afunya, Sales Manager
under +233 244 796007 or +233 303 404452

E-Mail: sales@pkfscientific.com
pkfscience@yahoo.com
kafunyapkfscience@gmail.com

This method is to be followed:

1. Take a representative soil sample (see Chapter 5).
2. Take a small container of about ½ litre of volume.
3. Mix 1 part of soil with 2 parts of water (by volume).
4. Stir well for 30 minutes and let sit for 2 hours.
5. Dip in the indicator strip for a few seconds.
6. Compare the colour change with the chart and read the pH value (between 4.0 and 5.8)

Use pH indicator strips for a quick pH test in the field.

Some fertilisers can make the soil more acid (see Table 10). Do not use them if your soil is already at risk.

The most direct method to increase plant nutrient availability and growth in acid soils is to neutralise acidity by adding lime (Calcium carbonate), dolomite (Calcium-magnesium carbonate), wood ashes or compost.

Table 2: Lime application rates to raise soil pH by approximately 1 unit

Lime Application Rates*	Sandy soil	Loamy soil	Clayey soil
kg per mango tree	4	5	6
kg per 100 m^2	10	12	17
50-kg bags per acre	8	10	14

* Lime application rates are for dolomite and ground limestone assuming a soil organic matter level of approximately 2% or less. Increase the lime application rates by 20% on soils with 4-5% organic matter.

Individual applications should not exceed 25 kg per 100 m^2. Over liming (e.g. liming soils to pH 7 or higher) can induce Phosphorus and micronutrient deficiencies. Annual doses of lime therefore should be relatively small.

Use only agricultural lime (e.g. from "Golden Stork / Dreyfus"). Avoid the use of hydrated or burned lime.

For tree crops, apply the lime – as well as all other fertilisers – on the drip line around the tree in a 1-m wide band.

Exercise 3

A. For a planned mango orchard the soil pH is 4.8. Is this pH value suitable? What needs to be done?

B. After liming a block of land for pineapple growing the soil test shows a pH of 7.5. What are the consequences? What should be done?

5. Taking soil samples

For soil chemical analysis, a representative soil sample should be taken from the field. It is important that samples are taken from uniform areas with the same history of usage.

The samples should be taken either along the Z-plane or the Y-plane.

Figure 2a: Sampling along a Z-plane in a field plot

O denotes equidistant sampling spot

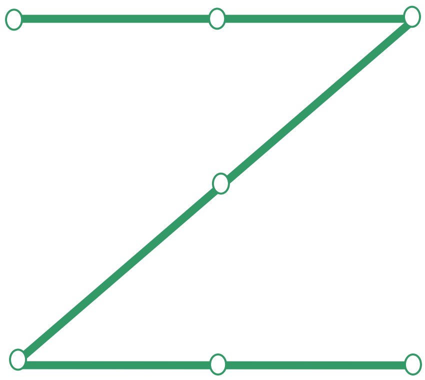
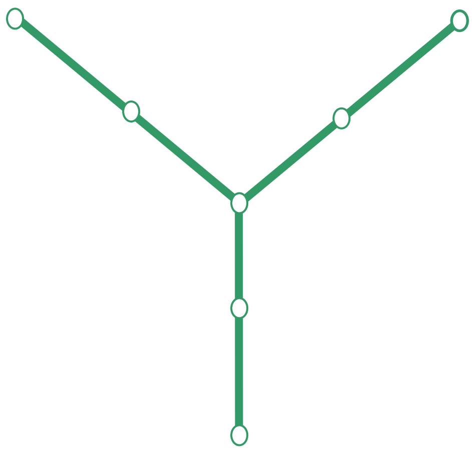


Figure 2b: Sampling along a Y-plane in a field plot

O denotes equidistant sampling spot



Clear site and remove all above ground biomass until soil surface is revealed. Take a sample either from the layer 0-15 cm or 15-30 cm.

For annual crops and pineapples samples are only taken from the layer 0-15 cm. For tree crops, take the first sample from the layer 0-15 cm and the second sample from the layer 15-30 cm.

Remove un-decomposed plant materials and package the soil samples according to depth of sampling.

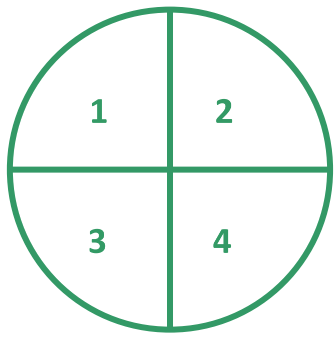
Air-dry soil samples at home. Spread out the dried sample in a circle and then take combined samples by taking a handful from each of the four quarters (see Figure 3).

The sample is then put into plastic bags.

Labelling:

- ✓ Add a label from non-perishable material inside the bag.
- ✓ In addition, label the bag on the outside, too.

Figure 3: A sample of air-dried soil is taken from 1st, 2nd, 3rd and 4th quarters



The following information is put on the label:

- ✓ Date of sampling
- ✓ Depth of sampling (from … to …)
- ✓ Name of person doing the sampling
- ✓ Description of plot
- ✓ GPS Coordinates (taken with a GPS handset)
- ✓ History of the site (previous use, grazing, etc.)

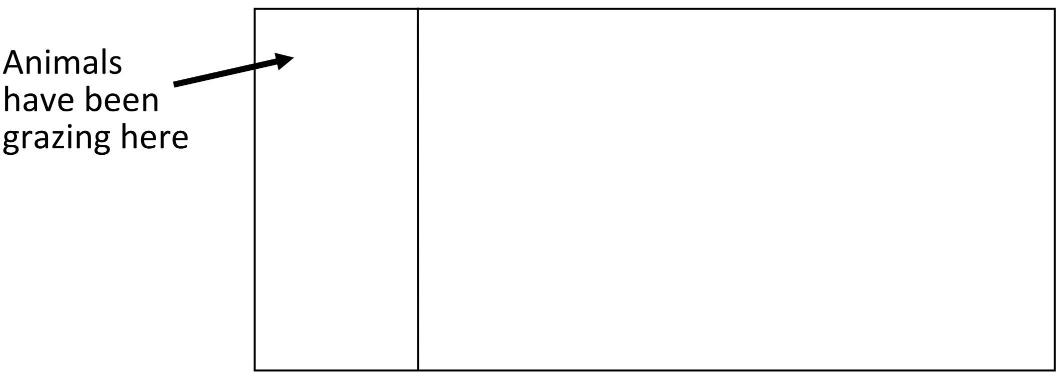
The below table is a check list in preparation for soil sampling.

Table 3: Preparation for soil sampling

Item	Function	Tick
Field note book	Recording of soil sampling activities	
Plastic bucket	Mixing of soil samples	
Auger, spade & trowel	Sampling soil	
Cutlasses	Weeding, digging and measuring soil depth	
Sampling bags	Storing soil samples	
Permanent marker	Labelling soil samples	
Labels	To be placed in the soil **and** on the sampling bag	

Exercise 4

The crop is 8-year old mango trees planted 10 x 10 m. The field size is 100 x 200 m.



Indicate on the map how you would take representative samples (pattern, where to take samples, how many, etc.).

The table below shows some selected soil laboratories in Ghana. Prices are subject to change. Enquiries should always be made before committing to a particular soil lab.

Table 4: Selected soil laboratories in Ghana

CSIR Soil Research Institute, Kwadaso, Kumasi (Web: www.csir-sri-org) Dr. Francis Tetteh, Mobile: +233 244622124, +233 24450353, Tel.: +233 322050275 Basic soil analysis: 25 GHC, Complete soil analysis: 40 GHC Provides also soil analysis interpretation and suggests management options.
CSIR Soil Research Institute, Accra, www.csir-sri-org, enochboateng06@gmail.com Mr. Enoch Boateng, Tel.: +233 302778226, Mobile: +233 244732410 pH: 5 GHC; Total N, Available K, Available P: 15 GHC each; micro-nutrients: 30 GHC Provides also soil analysis interpretation and suggests management options.
CSIR Savannah Agricultural Research Institute, Nyankpala, Tamale Mr. Crosper, Mobile: +233 243287336; Dr. Fosu, Mobile: +233 244749893 Average per element: 6.5 GHC; Standard soil analysis: 59 GHC (includes N, P, K, Mg, Ca, CEC, TEB, Organic Matter, pH, Texture)
SGS Ghana Limited, 5 Gowa Lane, Roman Ridge, P.O. Box 732, Accra Tel.: +233 30320504514, +233 3027739 94/95, E-Mail: sgslabho@ncs.com.gh N: 25 USD; Total P: 26 USD; K: 17 USD; pH: 6 USD (plus a batch fee and VAT)
University of Ghana, Faculty of Agriculture, Soil Science Department, Legon, Accra Mr. Benart-Anipa, Mobile: +233 243104878 N, K: 20 GHC each; P: 25 GHC; Organic Matter: 30 GHC; pH: 5 GHC; Texture: 30 GHC; S, Ca, Mg: 15 GHC each; Zn: 45 GHC; CEC: 30 GHC
KNUST, Kwame Nkrumah University, Crop Science Department, Kumasi Mr. Samual Acquah, Mobile: +233 244560309 Each nutrient: 10 GHC; Organic Matter: 10 GHC; pH: 5 GHC; CEC: 20 GHC Basic soil analysis: 50 GHC
University of Cape Coast, Cape Coast Mr. Kwabena Osei-Agyeman, Mobile: +233 243512614 or +233 268674502 N, K: 20 GHC each; P: 25 GHC; Organic Matter: 30 GHC; pH: 5 GHC; Texture: 30 GHC; A basic soil analysis (texture, pH, N, P, K) costs about 25 GHC per sample

6. Interpreting soil test results

Soil tests help to evaluate the availability of nutrients in the soil. However, they do not give any information about the nutritional status of the current crop growing in the soil as they cannot indicate whether plants are able to uptake the nutrients. The soil may be too acidic, too dry or too much compacted.

When you get the soil test results from the soil lab, go by the following 5-step process to calculate the amount of fertiliser to be applied to you crop:

1. **Classify** the nutrient availability in your soil into

high
adequate
low
very low

2. **Determine the amount of nutrients needed for replacement** of the nutrients removed by harvest.
3. **Adjust** this amount according to nutrient classes.
4. **Select a fertiliser mix**.
5. **Calculate the necessary amount of fertilisers** needed to supply the calculated amount of nutrients.

6.1 Classify nutrient availability (very low, low, adequate, high)

How to know if the nutrient levels in the soil are low, adequate or high? Table 5 helps to interpret soil test results.

However, the nutrient level also depends on the soil type and the crop the farmer wants to grow. The CSIR Soil Research Institute, for example, therefore provides you with a detailed interpretation of the soil test results as well as recommended management options.

Table 5: Soil test interpretation guide

(a) Macronutrients (N, P, K)

	Nitrogen (N)		**Phosphorus (P)**		**Potassium (K)**		
Extraction method	Kjedahl	2N KCl	Bray	Olsen	Ammonium Acetate		Ammonium Bicarbonate DTPA
					Base	Available	
Units	%	ppm	ppm	ppm	meq/100g	ppm	ppm
Levels:							
High	0.23-0.30	41-75	40-100	>25	0.7-2.0	280-800	121-180
Adequate	0.13-0.23	20-41	20-40	15-25	0.45-0.70	175-280	61-120
Low	0.05-0.13	<20	<20	<15	<0.45	<175	<60
Very low	Visible deficiency symptoms		Visible deficiency symptoms		Visible deficiency symptoms		

(b) Macronutrients (Ca, Mg, S)

	Calcium (Ca)		**Magnesium (Mg)**		**Sulphur ($S\text{-}SO_4$)**
Extraction method	Ammonium acetate		Ammonium acetate		KCl 40
Units	meq/100 g	ppm	meq/100 g	ppm	ppm
Levels:					
High	>10	>2000	>1.5	>180	>10
Adequate	5-10	1000-2000	0.5-1.5	60-180	5-10
Low	<5	<1000	<0.5	<60	<5
Very low	Visible deficiency symptoms		Visible deficiency symptoms		Visible deficiency symptoms

(c) Micronutrients

	Iron (Fe)	Manganese (Mn)	Zinc (Zn)	Copper (Cu)	Boron (B)
Extraction method	DTPA	DTPA	DTPA	DTPA	DTPA
Units	ppm	ppm	ppm	ppm	ppm
Levels:					
High	>5.0	>2.0	>1.5	>2.0	>2.0
Adequate	2.5-5.0	0.6-2.0	1.0-1.5	0.6-2.0	0.5-2.0
Low	<2.5	<0.6	<1.0	<0.6	<0.5
Very low	Visible deficiency symptoms				

(d) Soil properties (pH, organic matter, CEC, TEB, Base Saturation)

Parameter	pH	Organic matter (%)	CEC	TEB	Base Saturation (%)
Levels:					
High*	>6.5	>2.5	>20	>20	>95
Adequate*	5.5-6.5	1.5-2.5	5-20	4-20	85-95
Low*	<5.5	<1.5	<5	<4	<85

* also depends on the crop!

Exercise 5a

Which nutrient levels does the soil test indicate?

PARAMETER	VALUE	LEVEL
Nitrogen (N) Kjeldahl	0.17 % & no deficiency symptoms	________
Phosphorous (Bray)	10 ppm & deficiency symptoms observed	________
Available Potassium	170 ppm & no deficiency symptoms	________

Exercise 5b (Crop: Pineapples)

Look at the soil test results for the indicated crop and comment on each figure (very low, low, medium, high). What to do?

PARAMETER	VALUE	COMMENTS
pH	4.6	______________________________
% Organic Matter	1.09	______________________________
Ca (ppm)	562	______________________________
Mg (ppm)	195	______________________________
K (Base, ppm)	106	______________________________
CEC	6.27	______________________________
Avail. P (Olsen, ppm)	6.62	______________________________
Avail. K (ppm)	90.39	______________________________
Textural Class	Sandy Loam	______________________________

What to do?

Exercise 5c (Crop: Mangoes)

PARAMETER	VALUE	COMMENTS
pH (H_2O)	4.68	______________________________
Electric Conductivity	1.43	______________________________
N (%)	0.07	______________________________
Available P (mg/kg)	9.57	______________________________
Available K (mg/kg)	62.56	______________________________
% Organic Matter	1.40	______________________________
TEB	9.23	______________________________
CEC	9.43	______________________________
BS (%)	97.88	______________________________
Textural Class	Loam (46% Sand, 15% Clay)	____________________

What to do?

6.2 Determine amount of nutrients needed for replacement

Any crop removed from your plot also removes nutrients. These lost nutrients need to be replaced. Table 6 shows how much Nitrogen, Phosphorous and Potassium are lost with the harvest.

Table 6: Nutrient removal – per ton of crop

Crop	Nitrogen (kg N per t)	Phosphorous (kg P_2O_5 per t)	Potassium (kg K_2O per t)
Maize (only grains)	14	6	5
Pineapple (only fruits)	4	1	10
Mango (only fruits)	3	1	6
Citrus (only fruits)	9	2	11
Papaya (only fruits)	3	3	5
Cabbage	6	2	5
Eggplant	5	1	9
Okra	10	4	8
Tomato	7	2	13
Pepper	4	1	5
Cucumber	3	2	5
Water melon	5	2	9
Carrot	3	2	4
Onion	3	1	3

Now work out the actual expected nutrient removal. Estimate the projected yield in tons per acre and then calculate how much of Nitrogen, Phosphorous and Potassium is going to be removed per acre. Don't count any proportion of the yield that will be recycled to the field/orchard. Only what is actually removed for good needs to be taken into consideration.

Pineapple fruits contain 4 kg N per t, 1 kg P_2O_5 per t and 10 kg K_2O per t. A yield of 20 t/acre removes:

4 x 20 kg = 80 kg N per acre,
1 x 20 kg = 20 kg P_2O_5 per acre, and
10 x 20 kg = 200 kg K_2O per acre (see Table 7).

Table 7: Nutrient removal – per acre

Crop	Nitrogen (kg N per acre)	Phosphorous (kg P_2O_5 per acre)	Potassium (kg K_2O per acre)
Mango (6 t per acre)	18	6	36
Pineapple (20 t per acre)	80	20	200
Maize (2 t per acre) with residues left in the field	28	12	10
Maize (2 t per acre) with crop residues removed	32	20	40

6.3 Adjust according to nutrient level

If soil analysis results indicate adequate levels, only those nutrients that are lost with the harvest have to be replaced. However, if the analysis results indicate low or very low levels, additional amounts of nutrients need to be added.

Relate your expected nutrient removal (Table 7) to the soil test result. Apply a factor for each of the four nutrient levels (Table 8) and work out the actual amounts of nutrients to be added.

Table 8: Adjustment according to nutrient level

Nutrient level	Nutrients to be added
High	Multiply nutrient removal by 0.5
Adequate	Multiply nutrient removal by 1.0
Low	Multiply nutrient removal by 1.5
Very low	Multiply nutrient removal by 2.0

Exercise 6

In a pineapple field, the Nitrogen level is “adequate”, the Phosphorous level is “very low” and the Potassium level is “low”. The target yield is 20 t per acre. How many kg of N, P_2O_5 and K_2O need to be added per acre?

______ kg N per acre ______ kg P_2O_5 per acre ______ kg K_2O per acre

6.4 Select a fertiliser mix

To satisfy the need of your crop for different nutrients at different stages of crop development, you need to decide on the combination of different fertilisers. The following principles guide you for the right choice and timing of fertilisers:

1. Apply **Potassium and Phosphorous once per year** at the start of the season (e.g. for maize before ploughing and for mango after harvest).

   Nitrogen fertilisers should be applied in **two or three applications**. For example, if the total Nitrogen need of maize is 32 kg N/acre, then apply 50% at sowing (urea), 25% at 6-leaf stage (e.g. Ammonium nitrate) and 25% when tasseling is about to start (e.g. Ammonium nitrate).
2. First apply as much **organic fertiliser** as possible (manure, compost, cocoa shells, empty fruit bunches of oil palm). Then top up with mineral fertilisers to the amount of nutrients needed.

   Remember: There is more than 1 kg of K_2O in 100 kg of **empty fruit bunches**. A ton of empty fruit bunches is equal to 20 kg of Potassium chloride fertiliser. The bunch ash contains up to 40% K_2O.

   Cocoa shells even contain about 2 kg of N and 3 kg of K_2O per 100 kg.

   And there is as much as 4 kg of P_2O_5 in 100 kg of **poultry manure**.
3. Avoid compound fertilisers for your early Phosphorous and Potassium applications, as you will often waste the Nitrogen component in the fertiliser which is not needed at the early stage of the crop.
4. The preferred **Phosphorous** fertiliser is Rock phosphate. It is inexpensive, lasts long in soil (up to 5 years) and makes the soil less acid. The availability of P in Rock phosphate is good in soils below pH 6.5. But in soils with a higher pH, its availability is very slow.
5. The preferred **Potassium** fertiliser is Potassium sulphate. Many fruits (e.g. mango, citrus, pineapple, avocado, cashew and cocoa) and vegetables (melons, onions, cucumbers, tomatoes and chilli) are susceptible to Potassium chloride which should be avoided for these crops. For pineapples and tomatoes, Potassium chloride can be used, but only before planting / sowing.
6. The preferred **Nitrogen** fertiliser is Potassium nitrate as it has no acidifying effect and adds Potassium to the soil. Be aware that the Nitrogen becomes available very fast in Nitrate fertilisers (such as Potassium nitrate, Ammonium nitrate) and not so fast in Ammonium fertilisers. On the contrary, the Nitrogen in urea needs long to become available. Urea must be worked into the soil immediately after application to avoid Nitrogen losses.

6.5 Calculate the necessary amount of fertilisers

The soil test result together with your expected yield tells you the amount of nutrients to be added to the field. Tables 9 and 10 help to calculate the amount of fertiliser needed to supply those nutrients.

Table 9: Nutrient content of manures and some common waste materials

Fertiliser	**kg N per 100 kg**	**kg P_2O_5 per 100 kg**	**kg K_2O per 100 kg**	**% dry matter**
Sheep manure	2.0	1.1	2.8	60
Cattle manure	0.7	0.5	0.6	30
Pig manure	1.0	0.7	0.8	30
Poultry manure	1.8	4.0	1.7	75
Cocoa shells	2.5	2.3	3.0	80
Empty fruit bunch of oil palm	0.2	0.1	1.2	40

Table 10: List of fertilisers – their nutrient content and acidifying power

Fertiliser	**% N**	**% P_2O_5**	**% K_2O**	**% Ca**	**% S**	**Soil acidification***
Ammonium nitrate (NH_4NO_3)	34	0	0	0	0	++
Ammonium sulphate	21	0	0	0	24	+++
Ammonia	16-25	0	0	0	0	+
Potassium nitrate (KNO_3)	13	0	44	0	0	0
Urea	45	0	0	0	0	++
Rock phosphate	0	28-35	0	0	0	0
Triple superphosphate	0	46	0	14	2	0
Potassium chloride (KCl)	0	0	60	0	0	0
Potassium sulphate (K_2SO_4)	0	0	52	0	16	0

* Soil acidification: **+++** → strong acidification, **makes soil very acid**
++ → moderate acidification, **makes soil acid**
+ → light acidification, **makes soil a little acid**
0 → no acidification, **doesn't make soil acid**

In Exercise 6 we calculated that for a 1-acre pineapple field, 80 kg N, 40 kg P_2O_5 and 300 kg K_2O need to be added.

For half the N, we decide to use urea containing 45% N.

100 kg of urea	contain	45 kg N
??? kg of urea	contain	40 kg N

The answer is: 100 ÷ 45 x 40 = **89 kg of urea** contain 40 kg N.

For the remaining N, we decide to use Potassium nitrate (KNO_3) containing 13% N.

100 kg of KNO_3	contain	13 kg N
??? kg of KNO_3	contain	40 kg N

The answer is: 100 ÷ 13 x 40 = **308 kg of Potassium nitrate** contain 40 kg N.

For the P, we decide to use Rock phosphate containing 35% P_2O_5.

100 kg of Rock phos.	contain	35 kg P_2O_5
??? kg of Rock phos.	contain	40 kg P_2O_5

The answer is: 100 ÷ 35 x 40 = **114 kg of Rock phosphate** contain 40 kg P_2O_5.

For the K, we are aware that we have already applied some with the Potassium nitrate (KNO_3) containing 44% K_2O. We have applied 308 kg of Potassium nitrate. How many kg of K_2O is this?

100 kg of KNO_3	contain	44 kg K_2O
308 kg of KNO_3	contain	??? kg K_2O

The answer is: 44 ÷ 100 x 308 = 136 kg K_2O is already supplied. Therefore another 164 kg K_2O still need to be supplied.

For this remaining K, we decide to use Potassium sulphate containing 52% K_2O.

100 kg of K_2SO_4	contain	52 kg K_2O
??? kg of K_2SO_4	contain	164 kg K_2O

The answer is: 100 ÷ 52 x 164 = **315 kg of Potassium sulphate** contain 164 kg K_2O.

Exercise 7

The soil analysis results indicate adequate levels for P and K. You harvested 7.5 t of mangoes per acre.

a. How much Triple superphosphate do you need to purchase to replace the removed Phosphorous?

b. How much Potassium sulphate do you need to purchase to replace the removed Potassium?

c. You would like to use the 15-15-15 fertiliser. How much would you apply? And which disadvantages result from using this fertiliser?

Exercise 8

Your crop is pineapples. You are expecting a yield to take off your one acre field of 25 tons. Your soil test results are as follows:

Nitrogen: 0.10 %

Phosphorus (P) Bray: 18 ppm

Potassium (K) Acetate Available: 120 ppm (deficiency symptoms observed)

Work through the steps as above and calculate the amounts of different fertilisers needed to be applied!

7. Appendix

Table 11: Conversion table

From	To	Multiply by	From	To	Multiply by
NH_4	N	0.777	N	NH_4	1.285
NO_3	N	0.226	N	NO_3	4.427
P_2O_5	P	0.436	P	P_2O_5	2.291
K_2O	K	0.830	K	K_2O	1.205
$CaCO_3$	Ca	0.400	Ca	$CaCO_3$	2.497
CaO	Ca	0.714	Ca	CaO	1.399
$MgCO_3$	Mg	0.288	Mg	$MgCO_3$	3.467
MgO	Mg	0.603	Mg	MgO	1.657