



# **NATIONAL OPEN UNIVERSITY OF NIGERIA**

## **FACULTY OF AGRICULTURAL SCIENCES**

**DEPARTMENT  
OF  
Crop and Soil Sciences**

### **FPY/SIWES PRACTICAL GUIDE**

**SLM 401  
Soil Fertility and Water Management**

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### **IDENTIFICATION OF MINERAL DEFICIENCY SYMPTOMS**

#### **1.0 INTRODUCTION**

Soil fertility is the capacity to receive, store and transmit energy to support plant growth. It is the component of overall soil productivity that deals with its available nutrient status, and its ability to provide nutrients out of its own reserves and through external applications for crop production.

There are three main components of soil fertility - physical, chemical and biological (Abbott and Murphy 2003). The level of soil fertility results from the inherent characteristics of the soil and the interactions that occur between these three components. Most characteristics that contribute to the fertility of soil, such as soil pH and the susceptibility of the soil to compaction are dependent on the constituents of the original parent rock. Subsequent events, including the growth of plants and addition of fertilizer, modify the soil characteristics and alter its fertility.

Continuous use of acidic or salty synthetic fertilizers, insecticides, fungicides and herbicides disrupts the delicate balance between the three components of soil fertility. Competing land uses and extensive degradation are rapidly depleting the amounts of soils and water available for food production. In Africa alone 6.3 million hectares of degraded farmland have lost their fertility and water-holding capacity and need to be regenerated to meet the demand for food of a population set to more than double in the next 40 years.

Besides preventing deficit or surplus of water that affects development and yield and managing surface run-off to minimize erosion and nutrient leaching, water management has a major influence on soil fertility evolution. The soil water regime is closely interrelated with organic matter evolution, soil fauna development and soil physical property changes, especially in peat soil.

## **2.0 OBJECTIVE**

The main objective of this chapter is to acquaint students with soil fertility, plant nutrients and how to identify mineral deficiency symptoms in plants.

## **3.0 PROCEDURE**

### **Plant Nutrients:**

Of the 90 or so chemical elements forming the earth's crust, 16 are known to be essential for plant growth and reproduction. Seven elements needed in good quantity (macro nutrients) are hydrogen, oxygen, nitrogen and carbon from air and water and phosphorus, potassium and calcium from mineral particles in the soil. The other 9 elements needed only in small amount (micronutrients) are magnesium, sulphur, boron, copper, iron, manganese, zinc, molybdenum and chlorine.

Among others listed are cobalt and sodium as essential elements for plant growth. With the exception of hydrogen, carbon, and oxygen all other inorganic plant requirements are obtained directly or indirectly from the soil minerals, hence these elements are called mineral nutrients. Strictly speaking, nitrogen is not a mineral element but it has been included in the list because it can also be obtained by plants from soil.

The mineral elements are taken by plants from soils mostly in the form of ions. Plants obtain nutrients from the following four devices:

- (i) From the soil solutions through roots,

- (ii) From exchangeable ions on the surface of clay and humus particles through roots,
- (iii) From readily decomposable minerals, and (iv) through the leaves.

The essentiality of an element is proved by the following criteria:

- (a) The element may be considered essential if its exclusion from the nutrient medium inhibits or drastically reduces the growth and reproduction of plant.
- (b) Acute deficiency of the element produces certain well defined disease symptoms which are not produced by the deficiency of any other element.
- (c) Deficiency disease symptoms will disappear if the particular element is supplied before the living system has been damaged beyond repairs.

### **How Do Plants Receive Nutrients?**

All of these nutrients are taken in through the roots. Water transfers the nutrients from the soil to the plant roots, so water is important requirement for sufficient plant nutrition.

A second requirement is the appropriate soil pH for the plant being grown. Each plant prefers a specific pH range to be able to access the nutrients in the soil. Some plants are fussier than others, but if the soil pH is too acidic or alkaline, the plant will not be able to take in nutrients no matter how rich your soil may be.

### **Symptoms of Nutrient Deficiencies**

Plants will usually display definite deficiencies if required nutrients are not present in adequate concentrations. The following symptoms may occur if the level of one mineral nutrient is not high enough to be within the range needed for best plant growth. A plant may exhibit a particular symptom for reasons other than a nutrient deficiency. However, if one of the deficiency symptoms occurs, a lack of the proper nutrient may be suspected, and the amount of that nutrient should be increased.

<b>Deficient nutrient</b>	<b>Symptoms</b>
<b>Nitrogen</b>	Leaves are small and light green; lower leaves lighter than upper ones; not much leaf drop; weak stalk.
<b>Phosphorus</b>	Dark – green foliage; lower leaves sometimes yellow between veins; purplish color on leaves or petioles.
<b>Potassium</b>	Lower leaves may be mottled; dead areas near tips and margins of

	leaves; yellowing at leaf margins continuing toward center
<b>Calcium</b>	Tips of the shoot dies; tips of young leaves die; tips of leaves are hooked – shaped
<b>Magnesium</b>	Lower leaves are yellow between veins (veins remain green); leaves margins may curl up or down or leaves may pucker; leaves die in later stages
<b>Sulfur</b>	Tips of the shoot stay alive; light green upper leaves; leaf veins lighter than surrounding areas
<b>Iron</b>	Tips of the shoot stays alive; new upper leaves turn yellow between veins (large veins remain green); edges and tips of leaves may die
<b>Manganese</b>	Tips of the shoot stays alive; new upper leaves have dead spots over surface; leaf may appear netted because of small veins remaining green
<b>Boron</b>	Tip of the shoot dies; stems and petioles are brittle.

Not all plant problems are caused by insects or diseases. Sometimes an unhealthy plant is suffering from a nutrient deficiency or even too much of any one nutrient. Plant nutrient deficiencies often manifest as discoloration or distortion of the leaves and stems.

#### 4.0 SUMMARY

Of all the chemical elements forming the earth's crust, 16 are known to be essential for plant growth and reproduction. Seven elements needed in good quantity (macro nutrients) are hydrogen, oxygen, nitrogen and carbon from air and water and phosphorus, potassium and calcium from mineral particles in the soil. The other 9 elements needed only in small amount (micronutrients) are magnesium, sulphur, boron, copper, iron, manganese, zinc, molybdenum and chlorine. Among others listed are cobalt and sodium as essential elements for plant growth. With the exception of hydrogen, carbon, and oxygen all other inorganic plant requirements are obtained directly or indirectly from the soil minerals, hence these elements are called mineral nutrients. Nitrogen is not a mineral element because it can also be obtained by plants from soil.

#### 5.0 PRACTICAL ASSIGNMENT

1. 16 essential element are required in plant growth list these elements in order of their importance as macro and micro nutrients.

2. The mineral elements are taken by plants from soils mostly in the form of ions. Discuss the four different devices
3. Plants will usually display definite deficiencies if required nutrients are not present in adequate concentrations, identify the deficiency symptoms of the following elements: N P K and Ca.

## **ORGANIC AND INORGANIC FERTILIZERS AND METHODS OF APPLICATION**

### **1.0 INTRODUCTION**

Most of us know what fertilizers are as it is common to see them in market in retail shops. However, let us begin with the definition of fertilizers that are used for plants. Any material that supplies plants with the essential nutrients required for growth as well as optimal yield is known as a fertilizer. It may be natural or synthetic (artificially manufactured) and at the same time be organic or inorganic.

Organic fertilizers are natural materials that have an origin tracing back to plants or animals. They include green manure, livestock manure, compost, household waste, crop residues, woodland litter etc. On the other hand, inorganic fertilizers, also known as mineral fertilizers usually come from mining of mineral deposits. They need some processing and include phosphate, lime, rock, potash etc. They can also be manufactured industrially through chemical processes, an example of that being urea.

There are some important differences between organic and inorganic fertilizers in terms of their properties, applications and effectiveness. To begin with, organic fertilizers offer a very feasible option as they are available on or near the farm at little or no cost at all. For example, if a farmer has livestock, then livestock manure can also be used as a fertilizer and that is free of cost. As for inorganic fertilizers, the costs of labor, transportation, handling and the opportunity cost of the land being used for producing them make them very costly. Fertilizer use and application is labor intensive for organic but not so for inorganic fertilizers. This makes it possible to devote time and effort to other tasks on the farm provided that an inorganic fertilizer is being used.

### **2.0 OBJECTIVE**

The main objective of this chapter is to acquaint students with the meaning of fertilizer itself and two different types of common fertilizers that are either in organic or inorganic form and also to learn the methods of applying these fertilizers.

### 3.0 PROCEDURE

#### Mineral fertilizer

##### Role of fertilizers

Mineral fertilizers are materials, either natural or manufactured, containing nutrients essential to normal growth and development of plants. Fertilizers have become an integral part of the agricultural economy of developed countries but their use in developing countries is a comparatively recent occurrence. Amongst the various agricultural inputs, fertilizers perhaps next only to water, contribute the maximum to increasing agricultural production. It has been estimated that about 50 percent of the increase in agricultural production witnessed during the last decade in developing countries is attributable to fertilizer use.

All fertilizers are divided into organic and mineral fertilizers. Organic fertilizers are universal, they contain everything necessary nutrition elements for plants. For example, organic fertilizers is manure that contains about 0.5% nitrogen and 0.6% potassium, 0.25% phosphorus, etc. mineral fertilizer contain many times more nutrients than organic fertilizers. So, for example, nitrogen fertilizer contains 15% nitrogen (sodium nitrate,  $\text{NaNO}_3$ ) to 82% (liquid ammonia). Phosphate fertilizers contain from 18% phosphorus (phosphate rock) to 40%. Potassium fertilizers contain potassium from 16% to 62% (potassium chloride-KCl). In complex fertilizers contains nitrogen, phosphorus and potassium.

There are mineral fertilizers containing 1, 2 and 3 nutrients, therefore are called simple, double and complex. In addition, some complex fertilizers also contain trace elements such as copper, boron, zinc, manganese. Fertilizer are stored in dry cool place, the shelf life is not limited, but preferably not more than 2 years.

**Mineral fertilizers** are applied to the soil in early spring or autumn before the preparation of the soil. During plant growth the fertilizers also add. (Evenly scattered in dry form or watered).

#### Benefits of the elements contained in fertilizers

Thus, the lack of nitrogen in the soil causes the leaves lose color, become at first pale green, then turn yellow, stops the growth of new leaves, the same new leaves remain underdeveloped. With a lack of potassium in the soil reduced the similarity of seeds,

increases the susceptibility of plants to diseases, lower leaves first turn yellow in the edges, then turn brown and die. Phosphorus is needed by plants to accelerate the development of the root system and fruit. The lack of phosphorus in the soil affects the leaves, it turns grayish or reddish color, the lower leaves turn yellow and die.

Calcium contributes to the development of the root system. Sulfur "plays" a role in the processes of plant respiration; magnesium and iron, consumed by plants in much smaller quantities, also required for their normal development. Magnesium and iron supports the normal color of the leaves. In addition to the described elements necessary for plants growth we have boron, copper, manganese and zinc. With a lack of copper on the leaves of plants appear white spots, the leaves curl and dry up, stops the growth of plants. In addition, copper improves resistance of plants to fungal diseases and increase fruiting. To replenish the reserves of copper in the soil it make copper sulphate ( $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ ), taking 10-20 grams of copper sulfate per 10  $\text{m}^2$ . Manganese is an important role in respiration of plants and in the process of photosynthesis. Manganese increases the yield of agricultural plants. Mineral fertilizers, which are the basis of manganese, used: fruit trees are sprayed before and after flowering with a solution containing 30 g of potassium permanganate with 1 liter of water. This can be combined with "Urea". In the main for vegetable crops take 60-100 g of potassium permanganate in 10  $\text{m}^2$  square. Zinc has beneficial effects to formation of organic acids in plants from carbohydrates and prevents a number of diseases of plants, especially citrus. Of course, it's best to use a complex fertilizers, containing a complete set of trace elements (boron, manganese, molybdenum, zinc, copper), and 11% of nitrogen, phosphorus and potassium. Such fertilizers are suitable for all soil types and are used for the main application.

### **Phosphate fertilizers**

Phosphate fertilizers – the most common are superphosphate, precipitate and phosphate rock. Simple superphosphate is a mixture of calcium dihydrogen phosphate  $\text{Ca}(\text{H}_2\text{PO}_4)_2$ , calcium hydrophosphate  $\text{CaHPO}_4$  and Calcium phosphate  $\text{Ca}_3(\text{PO}_4)_2$  and also apatite,

gypsum, and other impurities. Simple superphosphate is got with processing phosphorite and apatite with sulfuric acid. When processing mineral phosphate with phosphoric acid get double superphosphate, containing up to 50% of phosphorus oxide ( $P_2O_5$ ). During the mixing phosphoric acid with lime get precipitate  $CaHPO_4 \times 2H_2O$ .

The **phosphate fertilizers** include:

$Ca_3(PO_4)_2$  phosphate rock, bone meal  
 $Ca(H_2PO_4)_2 + 2CaSO_4$  - simple superphosphate  
 $Ca(H_2PO_4)_2$  - double superphosphate  
 $CaHPO_4 \times 2H_2O$  - precipitate  
 $NH_4H_2PO_4 + (NH_4)_2HPO_4$  - mofos - complex fertilizer

**Nitrogen fertilizers:**

$NH_3$  - ammonia (contains the largest mass fraction of nitrogen)  
 $NH_3 \times H_2O$  - ammonia water  
 $CO(NH_2)_2$  - urea  
 $NH_4NO_3$  ammonium nitrate  
 $KNO_3$  - potassium nitrate (indian)  
 $NaNO_3$  sodium nitrate (chilean)  
 $Ca(NO_3)_2$  - calcium nitrate (norwegian)

**Potassium fertilizers:**

$NaCl \times KCl$  - Silvinit  
 $KCl$  - sylvite (potassium salt)  
 $K_2SO_4$  is the potassium sulfate  
 $K_2SB_3$  - potash, wood ash, peat ash

**Organic fertilizer**

Plants absorb water and minerals from the soil, which is essential for growth, flowering, crop yield, and other vital activities. Soil is a store house for organic and inorganic plant nutrients. Some soils are rich in organic and humus content and are considered to be fertile and more productive while others that are deficient in humus and minerals are less productive.

The soil is subjected to a continuous depletion of nutrients due to its continuous use by crops. This requires the addition of mineral resources. The various soil components are being removed by living organisms and are returned to the soil by death and decay of organisms. If the rate of removal or loss of minerals is greater than the rate of addition,

the soil will naturally become less fertile. The minerals of the soils are lost due to crops, leaching or soil erosion.

The minerals are often removed from the top layer by rainwater. Cultivation of crops regularly, year after year, makes the soil less productive. In intensive cultivation there are little chances for the restoration of lost nutrients in the soil until they are supplied from outside. The leguminous plants, however, compensate the loss of nitrogenous compounds. Besides this, manure and fertilizers are to be supplemented to restore the fertility of the soil.

The deficiency of mineral nutrients in the soil either can be compensated through organic manures such as green manuring, compost etc. or it can be supplemented by the application of chemical fertilizers from outside sources.

### **Organic Manures:**

The organic content of the soil which is a good source of plant nutrients contributes most to the fertility of the soil.

### **Organic manures improve soil fertility in the following ways:**

- (i) They modify the physical properties as increase in granulation of the soil and increase in permeability and moisture holding capacity of soil.
- (ii) They provide food for soil microbes and thus enhance microbial activities.
- (iii) Decomposition products of organic manures help to bring mineral constituents of soil into solution.
- (iv) They improve physico-chemical properties of soil, such as cation exchange and buffering action.

### **Organic manures are of several kinds some of which are discussed below:**

#### **(i) Farmyard manures:**

Solid and liquid excreta as dung and urine of all farm animals are termed farmyard manures. They are ready made manures and contain nitrogen, phosphorus and potassium. The farmyard manures of different animals vary greatly in their composition but they are good for all types of soils and all the crops. Farmyard manure when collected in field in

exposed condition for several months' shows considerable loss of fertilizing value as upon decomposition a considerable amount of ammonia is lost by volatilization.

Therefore, it is important to keep manure protected from weather and manure preparation should be carried out in trenches of about a meter depth. When the trenches are filled with dung etc, the surface is covered with cow dung-earth slurry. In about 3 months the manure becomes ready for use.

### **(ii) Compost:**

Compost manure can be prepared from a variety of refuse materials, such as straw, sugar cane refuse, rice hulls, forest, litter, weeds, leaves, kitchen wastes. It is prepared in pits usually 6-8inlong, 1½ to 2inwide and one metre deep. In the pits, 30 cm thick layer of plant residues moistened with dung, urine and water is formed and then a second layer of about 30 cm thickness of mixed refuse is spread over it and moistened with slurry. The operation is repeated until the heap rises to a height of about 50 cm above the ground level. The top is then covered with a thin layer of moist earth. After three months of decomposition the material is well mixed and again covered. After a couple of months the manure is ready for use.

### **There are two types of composts:**

(a) Farmyard compost which is obtained from animal excreta and plant residues.

(b) Town compost which is obtained by decomposition of kitchen wastes and garbage of towns and cities. Compost manures are rich in all plant nutrients.

### **(iii) Green manures:**

Green manuring is the practice of growing, ploughing and mixing of green crops with soil to improve soil fertility and productivity. Its effects on soils are similar to those of farmyard manures. It is cheap and the best method to increase soil fertility as it can supplement farmyard and other organic manures without involving much cost. Green manures add nitrogen and organic matter to the soil for the improvement of crop yield.

Through green manuring mobilization of minerals, reduction of organic nutrient losses due to erosion, leaching and percolation, and improvement in physical, chemical and biological activities of the soil can be achieved. Green manuring also improves soil aeration and drainage conditions. For green manuring both leguminous and non-leguminous crops are used. In India, leguminous crops such as sannhemp (sanai),

dhaincha, berseem, clover, Phaseolusmungo, cowpea, are generally used for green manuring.

**(iv) Sawdust:**

Sawdust can be used as bedding material to conserve animal urine or for making compost. It is a low fertilizing material but it is definitely richer than wheat straw in calcium.

**(v) Sewage:**

In modern system of sanitation, water is used for removal of human excreta and other wastes.

**Sewage consists of two components:**

- (a) The solid part, called sludge and
- (b) The liquid part, called effluent or sewage water.

Sewage is quite rich in several plant nutrients and can be used for fertilizing the crop by irrigating the soil directly with sewage water but there is a danger for the spread of several human diseases.

#### 4.0 SUMMARY

Any material that supplies plants with the essential nutrients required for growth as well as optimal yield is known as a fertilizer. It may be natural or synthetic (artificially manufactured) and at the same time be organic or inorganic.

Organic fertilizers are natural materials that have an origin tracing back to plants or animals. They include green manure, livestock manure, compost, household waste, crop residues, woodland litter etc. On the other hand, inorganic fertilizers usually come from mining of mineral deposits. They need some processing and include phosphate, lime, rock, potash etc. They can also be manufactured industrially through chemical processes.

#### 5.0 PRACTICAL ASSIGNMENT

1. All fertilizers are divided into organic and mineral fertilizers. Organic fertilizers are universal; they contain everything necessary nutrition elements for plants, mineral fertilizer contain many times more nutrients than organic fertilizers, differentiate between these two fertilizers in terms of their nutrients content.

2. Briefly explain how to applied mineral fertilizers in the soil?
3. What are benefits of the following elements contained in fertilizers: NP and K?
4. What are the most common Phosphate fertilizers?
  
5. Discuss method of preparation of farmyard manures and compost

## **COLLECTION AND PREPARATION OF SOIL SAMPLES**

### **1.0 INTRODUCTION**

Soil analysis is a diagnostic instrument for soil fertility and basis for fertilizer recommendation; to known where and where not fertilizer is to be applied. Obtaining accurate and precise values has always being the basis of soil analysis.

### **2.0 OBJECTIVES**

The main objective of soil analysis from the agronomic point of view is therefore:

- 1) To satisfy the demand for soil classification data.
- 2) To generate information for management and improvement of the soil.
- 3) To determine the ecological effect of some agricultural production and environmental pollution.
- 4) To evaluate soil fertility in order to recommend fertilizer.

### **3.0 PROCEDURES**

Soil analysis is a diagnostic instrument for soil fertility and basis for fertilizer recommendation; to known where and where not fertilizer is to be applied. Obtaining accurate and precise values has always being the basis of soil analysis. From agronomic view, the aims of soil analysis are:

- 1) To satisfy the demand for soil classification data.
- 2) To generate information for management and improvement of the soil.
- 3) To determine the ecological effect of some agricultural production and environmental pollution.
- 4) To evaluate soil fertility in order to recommend fertilizer.

It is important to have a clear idea about the purpose of any soil analysis as this will help determine sampling technique, sample preparation methods, elements or fractions to be determined and the analytical techniques to be employed.

## General Principles of Soil Sampling

It is necessary to procure a test sample that will be representative of the soil under investigation and to prepare the test sample for analysis. This is because sampling errors are commonly greater than analytical errors. Analytical value can serve as an accurate description of the soil if the followings are true:

- 1) The gross sample accurately represents the whole soil from which it was taken.
- 2) No changes occur in the gross and subsamples prior to analysis.
- 3) The subsamples analysed represents the gross sample accurately.
- 4) The analysis determines a true value of the soil characteristics under investigation.

A soil or field may be assessed for its capability of providing a crop with essentials nutrients in several ways:

- 1) Field plot fertilizer trials
- 2) Greenhouse pot experiments
- 3) Crop deficiency symptoms
- 4) Biological tests such as growing microorganisms
- 5) Soil testing prior to cropping

All the approaches can be used in research, the latter one is most amenable and popular and one upon which recommendations for farmers can be based. On the other hand, plant analysis is a postmortem approach and one that should be interpreted in the light of soil test results. Most soil tests primarily focus on elements in most demand by crops which are supplied by fertilizers: N, P and K, others are Ca, Mg and S. In drier areas micronutrients such as Fe, Zn, Mn, Cu and B are often measured. As nutrient behavior in soils is governed by soil properties and environmental conditions, measurement of such properties is often required. These include pH, salinity, organic matter, CaCO<sub>3</sub> and texture in drier areas the presence of Na and gypsum (CaSO<sub>4</sub>.2H<sub>2</sub>O) is also of concern.

## Types of Sampling

- 1) Simple random sampling
- 2) Systematic sampling
- 3) Stratified sampling

## Phases of Soil Testing

- 1) **Sample collection:** This should be such that it reliably reflects the average status of a field for the parameter considered.

2) ***Extraction or digestion and nutrient determination:*** The reagent used and the procedures adopted should quantify all or a portion of the element in the soil which is related to availability to the plant i.e. it should be correlated with plant growth.

3) ***Interpreting the analytical results:*** The units of measurement should reliably indicate if a nutrient is deficient, adequate, or in excess.

4) ***Fertilizer recommendation:*** This is based upon the soil test calibrated for field conditions, and considers other factors such as yield target, crop nutrient requirement, management of the crop, soil type, and method of fertilizer application.

### **1) Soil Sampling**

Soil sample should be composed of several subsamples representing a seemingly uniform area or field with similar cropping and management history. There is no universally accepted numbers of subsamples for different field situations. However, the following points can serve as guidelines:

- (A) Composite sampling
- (B) Time of Sampling
- (C) Depth of Sampling
- (D) Sampling Tools

### **2) Field Processing**

### **3) Laboratory Processing**

## **LABORATORY FACTORS OF IMPORTANCE TO SOIL EXTRACTION**

These are factors that have significant impact on the test results. They include means of shaking, rate of reciprocation, type of extraction vessel, extraction time and laboratory temperature.

- 1) Extraction vessel shape:
- 2) Shaking vs stirring:
- 3) Shaking rates:
- 4) Extraction time:
- 5) Laboratory temperature:

## **DISSOLUTION FOR TOTAL ELEMENTAL ANALYSIS**

It is important to have a clear idea about the purpose of any soil analysis as this will help determine sampling technique, sample preparation methods, elements or fractions to be

determined and the analytical techniques to be employed. There are several types of soil analysis viz:

- 1) Elemental analysis
- 2) Fractional analysis
- 3) Total elemental analysis (TEA)

TEA determines the quantity of an element present in the soil without reference to the quality (available form or polluted form). TEA is achieved by either wet or dry ashing.

### **Wet ashing:**

Can be accompanied by use of nitric, sulphuric or perchloric acid in different combinations

### **Dry ashing:**

This is done in a muffle furnace at temp of 600°C but with high temperature

### **Testing for Soil pH and Soil Acidity and Lime Requirement**

pH measures relative acidity and alkalinity whereas soil acidity means the total amount of acid present in the soil. Quantitatively we use the pH scale in order to remove unwieldy figures e.g. 0.056M H<sup>+</sup>. P means – log. The pH scale could be derived from the ionization of water.

H<sub>2</sub>O ⇌ H<sup>+</sup> + OH<sup>-</sup> K<sub>w</sub> = activity of pure solid, liquid or gas in solution is 1.

At 25°C K<sub>w</sub> = 10<sup>-14</sup> (moles litre<sup>-1</sup>)

∴ (H<sup>+</sup>)(OH<sup>-</sup>) = 10<sup>-14</sup>

In pure water the concentration of (H<sup>+</sup>) and (OH<sup>-</sup>) are equal

(H<sup>+</sup>)(OH<sup>-</sup>) = 10<sup>-14</sup>

x x = x<sup>2</sup> = 10<sup>-14</sup> ∴ x = 10<sup>-14/2</sup> = 10<sup>-7</sup>

∴ (H<sup>+</sup>) = 10<sup>-7</sup>, (OH<sup>-</sup>) = 10<sup>-7</sup>

∴ pH = 7 of pure water

POH = 7 of pure water

pH scale runs between 0 and 14 and that pH 7 is neutral.

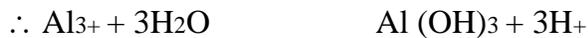
### **Application of pH to Soil**

Most mineral soil in the humid region has pH range between 3.5 to 7, while those of arid region have a range between 6.8 – 8.8. pH above 9 are found in alkali Na saturated soil and pH below 3.5 are found in acid organic soil (peat). pH is one of the most enlightening attributes of the soil, whether the soil pH is high or low will depend on the

solubility of certain compounds in the soil. pH of around 4 signifies the presence of free acids in the soil (usually from oxidation of sulphides), pH of 5.5 and below indicates the likely presence of  $\text{CaCO}_3$ . Measurement of pH means the H concentration in solution and its called the active acidity, the potential/reserve acidity is that left within the microcell. Cations in exchange site is in constant equilibrium with that in solution. pH measures the active acidity while potential acidity is determined by titration using a base.

### **Causes of soil acidity:**

- (1) Leaching loss of bases
- (2) Application of fertilizer especially N fertilizer;  $\text{NH}_4^+$  producing and  $\text{NH}_4^+$  containing fertilizer like urea and  $(\text{NH}_4)_2\text{SO}_4$
- (3) Acid rain
- (4) Decomposition of organic matter, here  $\text{CO}_2$  evolved react with soil water to form  $\text{H}_2\text{CO}_3$
- (5) Hydrolysis of aluminum.



### **Importance of Soil pH in Crop Production**

#### **Determination of pH**

There are 2 basic methods of determining the soil pH viz

- (1) Colorimetric and
- (2) Potentiometric method

In either method, the sample has to be prepared. The soil sample is weighed, then decision on the type of slurry to prepare (water slurry (distilled water)) or salt solution ( $\text{KCl}$  or  $\text{CaCl}_2$ ) 0.01M conc. of the salts are used. Decision on the ratio of water to soil or salt solution to soil, usually 1:1 or 2:1 (salt or water: soil). It is recommended that slurry should be shaken and read immediately because if allowed to settle, the potential difference as a result of the junction is avoided when settling is not allowed the actual reading is gotten.

#### **Colorimetric Method of pH Measurement**

This entails the formation of colour with soil:  $\text{H}_2\text{O}$  or salt solution mixture. The colour formation is made possible by the addition of a universal indicator (indicator with large pH range), the colour is then matched with colour charts of known pH. (Demerit – slower, less precise colour blindness and eye fatigue.)

## Potentiometric Method

This is an instrumental method and involves measurement of potential. It is based on the principle that if we use pH sensitive electrode (selective or specific electrode), the potential generated is proportional to the  $H^+$  concentration. i.e.  $E = K(H^+)$  It is based on the Nerst equation.

$E = E_0 \pm 0.059/n \log [H^+]$  ie  $E_0 \pm 0.059/n = K$ , holds only at 25°C.

pH is also known to be equal to  $(E - K) / 0.059$  @ 25°C hence the temperature should be adjusted to 25°C.

The pH is directly related to E. To establish this straight line, a minimum of two or more points is required. To establish this straight line, you have to calibrate the pH meter with standard buffers. There are 3 standard buffers pH 4, 7 and 9. The choice of buffer is a function of the experience, if acid soil use pH 4, 6 or 7 if alkaline use 6 or 7 and 9.

## Factors Affecting pH Measurement

- 1) Suspension effect
- 2) Dilution effect
- 3) Sodium effect:

## Lime Requirement

This is the amount of lime required to neutralize the acidity of the soil to a desired pH. There are several methods of determining lime requirement, out of which five are very common:

- (1) Field plot techniques
- (2) Titration with a base (soil/base titration)
- (3) Incubation studies
- (4) Use of buffer
- (5) Green house techniques

- 1) Field plot techniques/green house
- 2) Titration with a base
- 3) Incubation studies

Use of buffer: -

## Soil Organic Matter

### Determination of SOM

SOM is the plant and animal remains or debris at all stages of decomposition. Decomposed parts are called humus.

1) Measurement of CO<sub>2</sub> evolved during decomposition. This is achieved by destroying the CO<sub>3</sub> with conc. H<sub>2</sub>SO<sub>4</sub>. It only works in a very close analytical train.

2) Determination from the total Nitrogen values. It is assumed that 5% of SOM is N. (100/5 x value), this particular method is based on an assumption which may not hold at all time. It is known that N content of SOM could vary from as low as 3% to as high as 8%.

3) **Weight loss:** - This is achieved by destroying the SOM and estimated by difference in weight loss before and after the destruction. SOM is destroyed by (1) chemical method by the addition of H<sub>2</sub>O<sub>2</sub> or (2) By ignition in a furnace. Weight loss method is not a very accurate method because it may not get all the OM destroyed; it is however used when there is no other method.

4) **Estimation of the oxidizable carbon:-** This is the most popular method and most accurate. There are several techniques under this, but the most popular is the Walkley and Black (1939) method.

### Walkley and Black Procedure

This is a chromic acid oxidation procedure; it involves the oxidation of the SOM by chromic acid. In practice the chromic acid is generated insitu by the reaction between K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> and conc.

H<sub>2</sub>SO<sub>4</sub> then you back titrate with ferrous solution because the K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> and H<sub>2</sub>SO<sub>4</sub> are added in excess. By this we determine the oxidizable organic carbon, however not all the Organic Carbon is oxidizable, but we know that about.

1) 75 % of the organic carbon in organic matter is oxidizable hence to convert org. carbon =  $100 / 75 = 1.33$

2) Only about 58% of total organic matter is organic carbon. So to convert org. carbon to org. matter =  $100/58 = 1.724$

3) Milli-equivalent weight of carbon in (g) = 0.003

$12/4 = 3/1000 = 0.003\text{g}$

$\% \text{ org C} = \frac{\text{Titre value of blank (A)} - \text{Titre value of sample (B)} \times \text{Normality of titrant}}{\text{Weight of soil taken}} \times 100 \times 0.003 \times 1.33$

---

Weight of soil taken

$\text{Org. matter} = \text{Total Org. C} \times 1.724$

---

$\text{Org. matter} = \frac{(\text{A}) - (\text{B}) \times \text{N} \times 100 \times 0.003 \times 1.33}{\text{Weight of sample}}$

---

Weight of sample

### Testing for Available Nutrients

Available nutrient is that portion of soil nutrient, whose variations (increase or decrease) are reflected in the growth/yield of the crop. The major nutrients of interest in this course are nitrogen, P, K, Ca, Mg, Na, Mn, Fe, etc.

### Soil Nitrogen

This is perhaps the most needed nutrient element in most soils. About 90% of total N in the soil is in organic combination. In most soil, N content ranges as low as 0.01% to as high as 0.5%. Total N content of Nigerian soil is around 0.02 – 0.2% and the critical level is 0.15%.

### Methods of Determining N Levels in Soil

Plant take N as  $\text{NO}_3^-$  and  $\text{NH}_4^+$ , hence both are important in plant uptake. There is however, the inter conversion of both in the soil to different forms. In recent time, attention is focused on  $\text{NO}_3^-$  for many reasons.

- 1) The possibility of leached  $\text{NO}_3^-$  - polluting the underground water i.e.  $\text{NO}_3^-$  - going below root zone of plants.
- 2) From point of view of crop need. However, so far in Nigeria, total nitrogen is used mainly as the index of N availability to crops.

### Total Nitrogen Determination

There are 2 classical methods of determining total Nitrogen.

- 1) **Dumass (1831):-** This is a dry oxidation procedure.
- 2) **Kjeldahl method:-** This is the widely used method for determining total nitrogen and there are many form of this method viz macro, micro, semi-micro systems. The Kjeldahl method is made u of two steps viz: digestion step and distillation step. The two step

Kjeldahl system does not take into consideration the following compounds N-O compounds and the N-N compounds therefore, the two way system has to be modified in order to include N-O compounds as  $\text{NO}_3^-$ ,  $\text{NO}_2^-$ . There are some modifications viz:

1) **Salicylic (e.g. aspirin) acid modification:-** In this modification the sample is pre-treated with salicylic acid dissolved in conc.  $\text{H}_2\text{SO}_4$ , the  $\text{NO}_3^-$  with the salicylic acid form nitro compound, the nitro compound in acid medium will be converted to amino compound and the sample is then treated normally by adding all the reagent required for digestion in ordinary Kjeldahl system.

## Determination of Phosphorus

### Chemistry of P in the Soil

Plant takes their P in form of  $\text{HPO}_4^{2-}$  and  $\text{H}_2\text{PO}_4^-$ . Unfortunately the soluble form of P in the soil at any particular time is very small that it will not satisfy the crop yield. Labile P is the pool of P that replenishes soil P immediately the soluble P is depleted. Therefore available P = labile P + solution P. Labile P varies from soil to soil, hence the extractant varies too from soil to soil.

50 % organic

100% P Mineral 40 %

50 % inorganic Adsorbed P 10 %

Solution P < 0.01 %

### Criteria for Selecting Extractant for P

- 1) The extractant should rapidly dissolve or desorbs P and it should be time independent after 30 minutes.
- 2) It should maintain O.M. and soil clays in a flocculated form (no dispersion of OM or soil minerals).
- 3) It should not precipitate after dissolution.
- 4) It should not contain excess salts, buffers, or ions that will interfere with the analytical determination.
- 5) It should be easy to prepare, store or disposed of.

In practice some of the commonly used extractant include:

- 1) Bray 1 0.03M  $\text{NH}_4\text{F}$  in 0.025N HCl
- 2) Bray 2 0.03M  $\text{NH}_4\text{F}$  in 0.1N HCl
- 3) Olsen 0.5M  $\text{NaHCO}_3$ , pH 8.5
- 4) Hunter 0.05M  $\text{NaHCO}_3$  in 0.01M EDTA

- 5) Mehlich<sub>1</sub> 0.05N HCl + 0.025N H<sub>2</sub>SO<sub>4</sub>
- 6) Egner 0.02N Ca-lactate + 0.02N HCl
- 7) Ambic I 0.25M NH<sub>4</sub>HCO<sub>3</sub> + 0.01M (NH<sub>4</sub>)<sub>2</sub> EDTA + 0.01M NH<sub>4</sub>F + superfloc
- 8) Citric acid 1% citric acid
- 9) 0.01M CaCl<sub>2</sub> solution

### **Bray 1 Extractant**

0.03M NH<sub>4</sub>F in 0.025N HCl, here the F<sup>-</sup> ion complexes Al and Fe forming AlF and FeF (AlPO<sub>3</sub> and FePO<sub>3</sub> are P forms in the soil). Since Al and Fe is removed from AlPO<sub>3</sub> and FePO<sub>3</sub> then the P is left available for determination. NH<sub>4</sub>F also chelates Al and Fe in solution.

### **Bray 2 Extractant (0.03M NH<sub>4</sub>F in 0.1N HCl)**

This is also based on the same principle as Bray 1 however, because of the stronger strength of the acid in Bray 2, it is also able to dissolve some mineral P (rock phosphate, Apatite).

### **Olsen (0.5M NaHCO<sub>3</sub> at pH 8.5)**

At high pH, P is held by Ca as Ca<sub>3</sub>(PO<sub>4</sub>)<sub>2</sub>



If Ca<sup>2+</sup> is removed, more Ca<sub>3</sub>(PO<sub>4</sub>)<sub>2</sub> will be dissociated to counteract the effect of the removal (Le-Chatelier's principle) hence Ca is removed by NaHCO<sub>3</sub> even, Ca has a strong affinity for CO<sub>3</sub><sup>2-</sup> to form CaCO<sub>3</sub>, hence more Ca<sub>3</sub>(PO<sub>4</sub>)<sub>2</sub> dissolves.

If we continue to remove Ca by precipitating it as CO<sub>3</sub><sup>2-</sup>, the reaction goes to the right, more and more P will be released into solution. In addition NaHCO<sub>3</sub> in solution will also have NaOH, the NaOH will react with Fe in the FePO<sub>3</sub> to form Fe(OH)<sub>3</sub>, this will also release more P into solution.

### **Determination of Extracted P**

There are several methods of doing this, but the most common is the molybdate method. The classical molybdate method involves the use of certain reagents like Na molybdate and NH<sub>4</sub>MoO<sub>10</sub>. When these reagents react with P in solution, yellow phosphomolybdate is formed and the intensity of the yellow colour is determined colorimetrically. However, the yellow colour is not very sensitive and there is a limit to its detection, hence to enhance the sensitivity of the colour, it is reduced to blue colour by the addition of stannous chloride (tin chloride). Another common method is the use of antimony potassium tartrate and ascorbic acid solution to generate a blue colour, whose intensity is a function of the P concentration.

### **Exchangeable Cations**

Two principal methods used in determining total CEC are:

1) **Summation method**:- All the cations are displaced by a saturated solution of the displacing ion, usually a monovalent ion.  $\text{NH}_4^+$  (ammonium) ion is often used. The salt widely used is  $\text{NH}_4\text{OAc}$ , by adding this  $\text{NH}_4^+$  is furnished and all other cations will have been displaced. The cations will then be determined and summed up to give the total CEC. \_

**Colloids** +  $\text{NH}_4^+$  **Colloids** +  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{K}^+$  colloid usually the  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  is determined using atomic absorption spectrophotometer (AAS) while  $\text{Na}^+$  and  $\text{K}^+$  are determined using flame photometer, H and Al by AAS and by NaOH titration.

2) **Displacement method**: here we figure out (i) Displacing ion (ii) Index ion e.g.  $\text{NH}_4^+$  as Index ion

**Colloids** +  $\text{NH}_4^+$  + Ca, Mg,  $\text{K}^+$   $\text{Na}^+$  +  $\text{NH}_4^+$

With soil and  $\text{NH}_4^+$ , shake for 1 hour filter, the filtrate has cations, residue (solid) has  $\text{NH}_4^+$  return the residue to the beaker, then look for a displacing ion (monovalent cation) usually  $\text{Na}^+$  in form of acetate. Hence  $\text{NH}_4^+$  in solution is equivalent to all the cations.

### Determination of Available Sulphur

The best extractant for S is  $\text{Ca}(\text{H}_2\text{PO}_4)_2$ , it must contain about 500 ppm  $\text{PO}_4^{3-}$ . Phosphorus is more specifically fixed whereas S is not specifically fixed i.e. the adsorption energy is higher in P than in S (P is more tightly held than S). Therefore P can easily displace S on the adsorption site. Extract and determine S by colorimetry, gravimetry but most common is turbidimetric method, here  $\text{BaCl}_2$  is added to the extract.  $\text{BaCl}_2 + \text{SO}_4^{2-} \rightarrow \text{BaSO}_4 + 2\text{Cl}^-$ ,  $\text{BaSO}_4$  is formed, this is a turbid suspension, the turbidity of the solution is determined, hence to make it stay, a stabilizer is added e.g. Gelatin/Cum acacia, the resulting solution is determined by use of a spectrophotometer at 420nm wavelength.

- To remove any colour (to ascertain that only turbidity is measured and not colour), this is achieved by adding a decolorizer e.g. activated charcoal; this is added to the filtrate and then refilter before adding  $\text{BaCl}_2$  and measuring.
- Turbidimeter functions even in the presence of colour because it records reflection and refraction.

### Micro-Nutrients

They are Cu, Zn, Co, Mo, B, Fe, Mn. They are essential to crop growth but needed in small amount as far as fertilizer need is concerned; however they have equal importance as the macro elements.

Micronutrient analysis is not common in most analysis because of several reasons as:

- 1) Since their presence is in trace levels, hence the instrument used for the analysis must be highly sensitive; this is not only very costly but also not available in most laboratories.
- 2) Since they are present in trace amount, containers used for them may contaminate the sample to the extent that the error level could be very high (e.g. 90%) and therefore it requires well-trained personnel to handle micronutrient analysis.

**Extraction** by EDTA + HCl, DTA + HCl, Acid etc. for boron we can use hot-water and immediately they are extracted, we can use AAS to determine them, depending on the availability of lamp as every element has its own lam.

#### 4.0 SUMMARY

It is necessary to procure a test sample that will be representative of the soil under investigation and to prepare the test sample for analysis. This is because sampling errors are commonly greater than analytical errors. Analytical value can serve as an accurate description of the soil if the followings are true:

- 1) The gross sample accurately represents the whole soil from which it was taken.
- 2) No changes occur in the gross and subsamples prior to analysis.
- 3) The subsamples analysed represents the gross sample accurately.
- 4) The analysis determines a true value of the soil characteristics under investigation.

#### 5.0 PRACTICAL ASSIGNMENT

1. From the agronomic point of view what are the aims of soil analysis?
2. What are the Criteria for Selecting Extractant for Phosphorus?
3. There are several methods of determining lime requirement list five of the very common one available.
4. What are the five Causes of soil acidity?
5. List and explain the four Phases of Soil Testing

### **Soil water conservation techniques and erosion control methods**

#### **1.0 INTRODUCTION**

Soil and Water Conservation are activities that maintain or enhance the productive capacity of land in areas affected by or prone to soil erosion. Soil erosion, on the other hand, is the movement of soil from one part of the land to another through the action of wind or water. Thus, soil erosion by water is caused by raindrop impact surface sealing, and crust formation leading to high runoff rate and amount, high runoff velocity on long

and undulating slopes, and low soil strength of structurally weak soils with high moisture content due to frequent rains. Soil erosion by wind is caused by lack of vegetation cover, dry pulverized soils, strong wind speeds, and poor land management practices such as continuous tillage and over-grazing.

## 2.0 OBJECTIVES

The main objective of soil and Water Conservation is to maintain or enhance the productive capacity of land in areas affected by or prone to soil erosion.

## 3.0 PROCEDURES

**Soil and Water Conservation** are activities that maintain or enhance the productive capacity of land in areas affected by or prone to soil erosion. Soil erosion, on the other hand, is the movement of soil from one part of the land to another through the action of wind or water. Thus, soil erosion by water is caused by raindrop impact surface sealing, and crust formation leading to high runoff rate and amount, high runoff velocity on long and undulating slopes, and low soil strength of structurally weak soils with high moisture content due to frequent rains. Soil erosion by wind is caused by lack of vegetation cover, dry pulverized soils, strong wind speeds, and poor land management practices such as continuous tillage and over-grazing.

Therefore, SWC includes the prevention, reduction and control of soil erosion alongside proper management of the land and water resources. Effective erosion management involves:

- Reduction of the amounts and velocity of surface runoff,
- Maintaining good soil cover through mulching and canopy cover
- Conservation and retention of soil moisture,
- Prevention or minimizing the effects of raindrop impact on the soil
- Maintaining favourable soil structure for reducing crusting
- Re-shaping the slope to reduce its steepness and slope length so as to minimize runoff flows
- Maintenance or improvement of soil fertility, and
- Removal of unwanted excessive runoff safely.

Based on these principles, erosion control measures are grouped into two broad categories:

- (i) Preventive techniques, and
- (ii) Control measures.

The erosion preventative measures mainly comprise the *agronomic soil and water conservation* practices that improve land productivity without construction of structures. The erosion control measures involve the *construction of various structures* for the

control, diversion or conservation of runoff. For improved agricultural productivity, both the agronomic and structural measures of soil and conservation are necessary, especially on steeply sloping lands, where water conservation or drainage of excessive water are required.

### **What are soil and water conservation structures?**

Soil and water conservation structures include all mechanical or structural measures that control the velocity of surface runoff and thus minimize soil erosion and retain water where it is needed. They usually consist of engineering works involving physical structures, made of earth, stones, masonry, brushwood or other material for the construction of earthworks such as terraces, check dams, and water diversions, which reduce the effects of slope length and angle. SWC structures can be designed to either conserve water or to safely discharge it away. They supplement agronomic or vegetative measures but do not substitute for them. Suitability of SWC structure depends on:

- Climate and the need to retain or discharge the runoff.
- Farm sizes.
- Soil characteristics (texture, drainage, and depth).
- Availability of an outlet or waterway.
- Labor availability and cost.
- The adequacy of existing agronomic or vegetative conservation measures.

### **Determining amounts of runoff for design of SWC structures**

#### **Characteristics of surface runoff**

Surface runoff (or simply runoff) is the portion of precipitation that makes its way towards the stream channels, lakes or oceans as surface or subsurface flows. Runoff occurs when precipitation rate exceeds infiltration rate, and is the most destructive component of rainfall. In the design of SWC structures, the most important factors used are (i) peak runoff rates, (ii) runoff volume, and (iii) temporal distribution of runoff rates and volumes.

#### **Factors affecting runoff**

These include both catchment factors and rainfall factors.

#### **Catchment factors**

Runoff is influenced by catchment factors such as topography, vegetation, infiltration rates, soil storage capacity and drainage pattern. In addition the size of the catchment, its shape, orientation, geology and surface culture also affect runoff. The larger a catchment,

the more runoff it will generate. Slope steepness is particularly important as soil erosion is more prone on steeper slopes. Surface culture includes the soil tith, whether there is vegetative cover or not, and other land management activities, e.g. cultivation that would increase erosion.

### **Rainfall factors**

Rainfall factors associated with surface runoff and erosion include; rainfall amounts, storm duration, intensity and distribution, as well as seasonal patterns, e.g. Dry areas are more prone to erosion than wet areas because prolonged dry spells destroy vegetation cover, and rain storms tend to be high intensity and thus erosive. The most significant component of rainfall is its intensity, which is a function of the energy the raindrops impact on the soil. The intensity-duration relationship of rainfall gives an indication of expected runoff. For example:

$$I = a / (t+b)$$

Where: I = Rainfall intensity

T = Duration of rainfall (min)

a & b are constants

For any given duration, the graph or equation will indicate the highest average intensity which is probable for a storm of that duration. This is calculated as:

$$I = kTx/tn$$

Where,

T = is the return period in years

T = is the duration in minutes

**k**, **x**, and **n** are all constants

Calculations involving rainfall probability must relate to a chosen return period, e.g. for conservation works on small farms, about 10 years.

### **Time of Concentration (Tc)**

The storm duration which corresponds with the maximum rate of runoff is known as the time of concentration (Tc). It is assumed that during the time of concentration, all parts of the watershed are contributing simultaneously to the discharge at the outlet. Tc is also described as the longest time for water to travel by overland flow from any point in the catchment to the outlet. It is equivalent to the time it takes water to flow from the furthest corner of the catchment to the outlet.

## **Design storm**

A design storm is a storm of known return period. It is used as a basis for designing structures. For example, a 10-year, 1-hour rainfall is the maximum rainfall amount expected in a 1-hour period with a 10-year return period.

## **Design runoff rates**

The capacity to be provided in a structure that must carry runoff may be termed as the design runoff rate. Structures and channels are designed to carry runoff that occurs within a specified return period (TR). e.g. 10 years for vegetative waterways, and 100 years for permanent channels.

## **Estimation of surface runoff**

It is important to know the quantities of water to be handled. If the objective is to impound water e.g. dams, peak volumes are used, if the purpose is to convey water e.g. channels/waterways, peak runoff rates are used. It is necessary to estimate runoff or design of conservation and also conveyance structures, to avoid failure due to overtopping. Estimates of the rates of surface runoff therefore depend on two processes: (i) estimating the rate of rainfall, and (ii) estimating how much of the rainfall runoff becomes. The runoff rate is more crucial and is determined using various methods or equations as described here below:

## **The Runoff Coefficient**

The simplest method is to use a single coefficient which represents the ratio of rainfall loss. If half of the rainfall is “lost” by infiltration, the other half appears as runoff, then the coefficient, C is 0.5. Examples of runoff coefficients:

Woodland on flat sandy loam,  $C=0.10$

Woodland, flat tight clay  $C = 0.40$

Cultivated, hilly clay soil,  $C = 0.60$

Urban, rolling, 50% built up,  $C = 0.65$ .

## **Catchment Characteristics or Cook’s method**

The method consists of summing numbers each of which represents the extent to which runoff from the catchment will influence a particular characteristic. The effect of four features is considered in Cook’s method, which are (i) the relief, (ii) soil infiltration, (iii) vegetal cover, and (iv) soil surface storage. Each of these is considered in turn and the condition of the watershed compared with four descriptions, i.e. extreme, high, normal, and low. Each description/feature has a number. For example, an arithmetic total (e.g.

$30+10+15+10=65$ ) is the watershed characteristic and will lie between the extreme values of 100 and 25. The main problem of this method which estimates by addition is that the errors are propagated.

### **Runoff Curve Numbers**

This is an extension of Cook's method, which allows for variations in the physical conditions of a catchment and also the land use. Like in Cook's method, four variables are considered and in each case, a selection has to be made from a list of options. Ten categories of land use or cover are offered (row crops, pasture, woods, fallow, farmstead etc) with a choice of soil conservation practices such as contouring and terracing. The hydrologic condition of the catchment is graded good, fair or poor and a subjective assessment of this factor is designated one of four major hydrologic soil groups described earlier. The method relies on subjective non-measurable assessment.

### **The Rational Formula**

The Rational method predicts runoff through this equation:

$$Q = 0.0028CIA$$

Where:

Q = The design peak runoff rate in m<sup>3</sup>/s

C = Runoff coefficient (a function of catchment vegetation, slope, surface culture)

A = Area of the watershed in hectares

I = Rainfall intensity in mm/hr for the design return period and for a duration equal to the time of concentration of the watershed.

The Rational method is developed on the assumption that

(i) Rainfall occurs at uniform intensity for a duration equivalent to the time of concentration, and (ii) Rainfall occurs at a uniform intensity over the entire area of the catchment.

### **General principles for the design of SWC structures**

The design of SWC structures considers severity and extent of erosion damage or risks, the factors causing erosion, as well as the suitability of land to the identified intervention. SWC control measures are directed at protecting the soil from raindrop impact and hydraulic forces of runoff. The process involves three areas of attention: (i) Reduction of raindrop impacts on soil; (ii) Reduction of overland flows; (iii) Increase infiltration rate, and (iv) Slowing runoff velocities.

## Factors considered

Soil and water conservation structures are usually made by hand labour or machinery although some terraces develop naturally from vegetative barriers. They are particularly important on steep slopes where annual crops are grown and in marginal rainfall areas where there is a need to conserve rainfall in situ. The selection and design of structure depend on many factors such as:

- Climate and the need to retain or discharge runoff.
- Farm size and system (large or small-scale, mechanized or non-mechanized).
- Cropping pattern (perennial or annual, with or without rotations).slope steepness.
- Soil characteristics (erodibility, texture, drainage, depth, stoniness and risk of mass movement).
- The availability of an outlet or waterway for safely discharging runoff away from cropland.
- Labour availability and cost
- The availability of material e.g. stone
- The adequacy of existing agronomic or vegetative conservation measures.

## Structures for retention or discharge of runoff

Structure can be designed either to retain or discharge runoff. They can also be designed so that part of the runoff is retained but the excess, during heavy storms, is discharged. In the higher rainfall areas (e.g. over 1,250 mm per annum), where crops are rarely short of water, or where there is a risk of water logging at certain times, it is usually to design structures to discharge runoff if there is no suitable outlet such as a natural waterway, artificial waterway or grassed slope. Discharging water onto a footpath, road or existing gully would aggravate soil erosion. On large-scale farms it is usually possible to set land for waterways. In densely settled area this is much more difficult. In the drier areas (e.g. less than 750 mm per annum) it is usually desirable to keep rainwater in situ and to prevent runoff. Other factors that must be considered in reaching a decision, besides the availability of a discharge area or waterway, include the soil type, soil depth land slope and the risk, if any, of retaining water in situ. Soils in higher rainfall areas that are prone to water logging because they are shallow or because of the clay content, such as the grey soil (planosols) or black cotton soils (vertisols) in other areas, normally require structures that will drain water. Some soil on steep slopes, such as the areas with Andosols, it is better to drain water. Also, areas prone to landslides become unstable if they very wet, and conservation structures should be designed to drain the water away. When there is a need to discharge water but no suitable space for a waterway, there are two options. One is to change the land use to a permanent crop or fodder grass that does not require conservation structure. The other is to use contour barriers designed to conserve all the runoff.

### **Size of conservation structure**

The design of any structure to retain or discharge runoff should be based on a reasonable estimate of the volume of runoff (m<sup>3</sup>) to be retained or the peak rate of runoff (m<sup>3</sup>/s) to be discharged. A retention structure can rarely be made big enough to capture all runoff during exceptionally wet period, unless the catchment area is very small. One alternative with retention structures is to incorporate a spillway to take the overflow. Similarly the design of a structure to discharge runoff can rarely be based on the heaviest storm possible. Usually it is based on the heaviest storm that can be expected in a given period (e.g. 10 years) with the knowledge that a heavier storm, of a magnitude that occurs once in twenty, fifty or a hundred years, could take place (the frequency in years with which a storm of a given amount is likely to occur is known as the return period).

### **Risks**

The risk of damage due to an exceptional storm should be considered when designing structures. If the risk cannot be eliminated, it must be minimized by ensuring that the structures are stable when they are made and carefully maintained afterwards. Failure to pay attention to this point can lead to damage during heavy storms and greater erosion than erosion than if the structures had not been installed in the first place. Where there are a series of structures on a hills slope there is a risk if a structure is breached near the top, then those downhill would also get damaged.

### **Types of conservation structures**

The main SWC structural measures used on croplands comprise diversion ditches (cut-off) drains), retention (infiltration) ditches, terraces and waterways. Supportive cultural measures such as grass or vegetative material for stabilizing the structures are also required for selection of proper species. The identification of appropriate types of SWC structures should take into account the need to retain runoff in areas where water is short or discharge runoff where it is in excess. The design of structures to discharge runoff, such as diversion ditches and waterways, should be based on an estimate of the peak rate of runoff. Structures which are intended to discharge runoff should not be installed unless there is safe place for disposal of water e.g. a natural or artificial waterway or permanent vegetation. In higher rainfall areas e.g. areas receiving more than 1000mm of rain per annum and where crops rarely lack water or where there is a risk of water it is usually necessary to design structures to discharge runoff. However, it would be a mistake to design a structure to discharge runoff if there is no suitable outlet such as a natural waterway, artificial waterway or grassed slope. Discharging water onto a footpath, road

or existing gully will aggravate the problem of erosion. In the drier area (less than 750 mm per annum) it is usually desirable to keep rainwater in situ and prevent runoff.

### **Benefits of conservation structures**

Soil and water conservation bears benefits over a longer time span after construction. However, some benefits such as increased crop yields can be attained within the first year. In general, the benefits of SWC can be summarized as follows:-

- Increased agricultural productivity (higher yields, fodder for livestock)
- Conservation of potentially productive land i.e. SWC supports sustainable agriculture
- Reduced nutrient loss from the soil, and thus less fertilizer requirements
- Environmental conservation, by storing more water within the soil profile and thus improved catchment hydrology
- Soil drainage benefits in areas prone to floods or water logging,
- SWC benefits irrigation and drinking water supplies, by protecting reservoirs from sedimentation
- SWC protects infrastructure such as roads from erosion damage, e.g. gullies.

### **Limitations**

The planning and construction of SWC structures on smallholder farms can be complicated by the small sizes of plots on given slope. This is because farm boundaries are not necessarily aligned to the contour or following a natural feature such as a crest line or drainage line. Thus, it is difficult to get appropriate site and space for an artificial waterway. Sometimes, the best site for a waterway may already be occupied by a footpath or a gully. Attempting to plan one farm in isolation from the others is likely to cause failure. A catchment plan is needed but there are social implications which must first be resolved. SWC structures can be expensive to install. In particular, gully control structures can be very expensive. There is also a lot of labour needed to excavate terraces, especially bench terraces. SWC requires some level of engineering design, and thus technical know-hoe can be a limitation. SWC structures function by retaining water in-situ, thus denying runoff to downstream areas. This can be a potential source of conflict which should be addressed.

### **Management and maintenance**

SWC structures require regular maintenance and repairs if they get damaged. Grazing in cultivated lands treated with SWC structures should not be allowed as the animals can damage the structures. Instead, fodder should be cut and taken to animals preferably under cut and carry systems. Replanting vegetative materials and lining out of construction and channels should be done at least every season.

#### **4. SUMMARY**

Soil and Water Conservation are activities that maintain or enhance the productive capacity of land in areas affected by or prone to soil erosion. Soil erosion, on the other hand, is the movement of soil from one part of the land to another through the action of wind or water. Thus, soil erosion by water is caused by raindrop impact surface sealing, and crust formation leading to high runoff rate and amount, high runoff velocity on long and undulating slopes, and low soil strength of structurally weak soils with high moisture content due to frequent rains. Soil erosion by wind is caused by lack of vegetation cover, dry pulverized soils, strong wind speeds, and poor land management practices such as continuous tillage and over-grazing.

#### **5.0 PRACTICAL ASSIGNMENT**

1. State all the effective management procedures as required for the prevention, reduction and control of erosion.
2. What are the benefits of conservation structures
3. Discuss the size of conservation structure
4. What do you understand by the word design storm
5. Briefly explain soil and Water Conservation

#### **6.0 Reference**

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