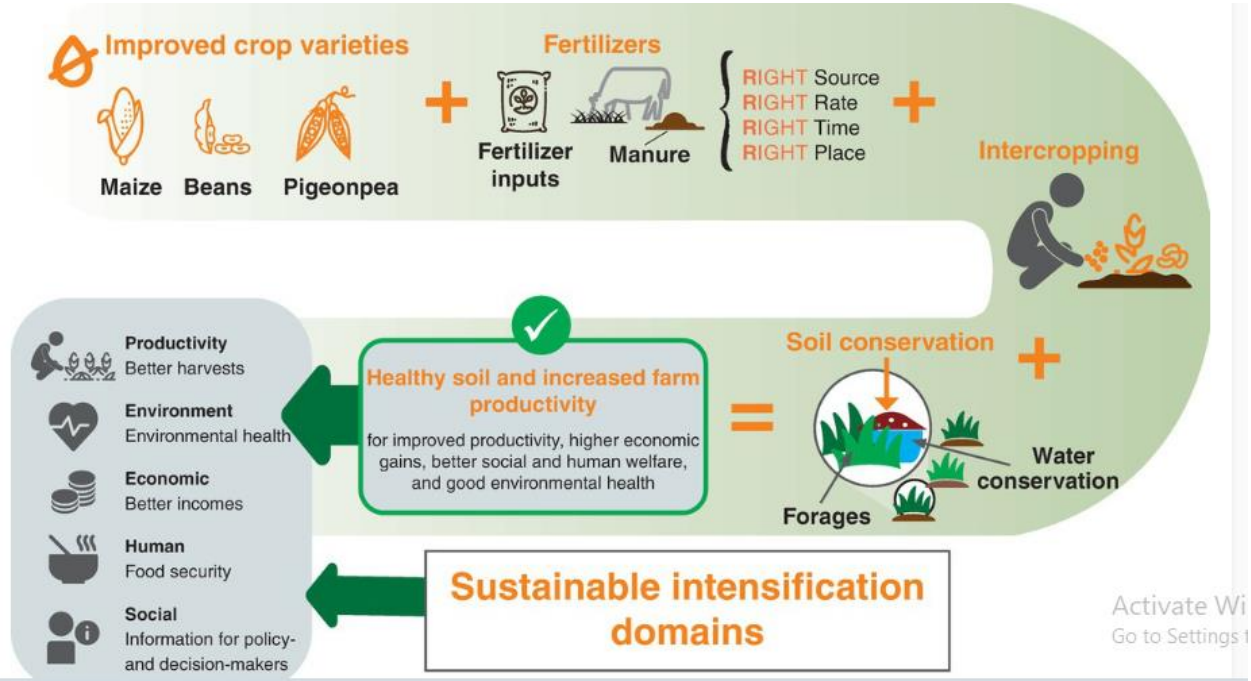
CROP PRODUCTION LEVEL- IV
Based on March, 2022 Version 4 Occupational standard



Unit Title: Manage Integrated Soil Fertility Management Technologies and Practices

Module Title: Managing Integrated Soil Fertility management Technologies and Practices

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Introduction to the module

This module specifies the knowledge, skills and attitude required to Select appropriate integrated soil fertility management (ISFM) strategy, determine relevant soil health and fertility management technologies for crop production, determine the requirements for soil health and fertility improvement for crop production, implement agro ecology principles and elements in production systems, document the soil health and plant nutrition program and specifications and monitor and evaluate soil health, fertility and crop production program.

LG #1	LO #1: Select appropriate integrated Soil Fertility Management (ISFM) strategy

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics:

- Site specification and profitable ISFM practices
- Socio-economic and biophysical challenges
- Local adaptation of requiring ISFM practices

This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Specify site and profitable ISFM practices
- Identify socio-economic and biophysical challenges
- Identify requirement of local adaptation ISFM practices

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below.
3. Read the information written in the information Sheets
4. Accomplish the Self-checks
5. Perform Operation Sheets
6. Do the “LAP test”

Information Sheet 1

Introduction

Integrated Soil Fertility Management (ISFM) is a set of soil fertility management practices that necessarily include the use of fertilizer, organic inputs and improved germplasm combined with the knowledge on how to adapt these practices to local conditions, aiming at optimizing agronomic use efficiency of the applied nutrients and improving crop productivity. All inputs need to be managed following sound agronomic and economic principles.

ISFM is a set of soil fertility management practices, including use of industrial fertilizer, organic inputs, and improved crop varieties, combined with knowledge on how to adapt the practices to local conditions. The aim of adopting ISFM is to maximize agronomic efficiency of the applied nutrients and improve crop productivity. All inputs need to be managed in accordance with sound agronomic principles.

Successful implementation of ISFM depends on starting with crop varieties of high productivity potential (genetic intensification). Any integrating technology contributes to attaining this potential by enhancing light, nutrient, and water use efficiency associated with the target crops. Resilience to biotic and abiotic stresses is an additional and desirable benefit of the improved crops.

The second dimension of ISFM involves applying fertilizers (organic and industrial) according to the 4 ‘R’s of nutrient stewardship. Intercropping and crop rotations promote useful legumes grown concurrently or in sequence with cereals. In intercrops, the legume component fixes atmospheric nitrogen to meet its own requirements, while sparing soil-derived nitrogen or nitrogen supplied through fertilizers, for the cereal crop. When the legume crop is of short duration, such as some cowpea varieties, it is possible for the intercropped cereal to benefit directly through legume litter decomposition within the same cropping season. In the medium to long term, the high-quality legume residues and residues from cereal crops result in maintenance or gradual build-up of soil organic matter, thus leading to sustainable crop production. Soil and water conservation practices can be tailored to local conditions.

Based on sound agronomic practices provided by ISFM, there have been large initiatives to enhance the uptake of no-tillage agriculture systems that integrate minimum soil disturbance, crop residue retention, and crop diversification. These benefit ISFM through minimum soil disturbance and improved soil cover, which in turn result in reduced soil erosion, increased water infiltration, efficient water use, and increased nutrient uptake. Over the longer term, no-till systems also lead to a gradual increase in soil fertility (soil carbon sequestration) and increased productivity. Such improved ISFM systems are commonly grouped under the concept of conservation agriculture.

1.1 Site specification and profitable ISFM practices

1.1.1. Site Specification for Integrated Soil Fertility Management (ISFM) Practices

Identify the specific soil types present in the target area. This could include clay soils, sandy soils, loamy soils, or a combination. Assess the soil fertility status, pH levels, organic matter content, nutrient deficiencies, and any other relevant soil characteristics.

Consider the climatic conditions of the region, including rainfall patterns, temperature ranges, and length of growing seasons. Identify the agroecological zones in the area, such as highland, midland, or lowland regions, as these can influence the choice of ISFM practices. Identify the major crops grown in the area and their specific nutrient requirements. Consider the crop rotation or intercropping systems commonly practiced.

Assess the availability and accessibility of local resources, such as organic materials (crop residues, manure and compost), mineral fertilizers, and soil amendments (lime, gypsum). Identify any constraints related to resource availability, affordability, or cultural practices that may impact the implementation of ISFM practices.

1.1.2 Profitable Integrated Soil Fertility Management (ISFM) Practices

A. Intercropping.

It refers to the practice of growing many crop varieties in close proximity on the same plot of land so as to maximize resource utilization. Intercropping has many benefits which include

improving soil cover and enhancing soil physical properties, weed controlling, minimizing pests attack on plants, controlling of diseases, promoting soil water conservation, and increasing water use efficiency among plants. Consequently, intercropping helps in improving soil fertility, decreasing soil nutrients loss and increasing crop yields.

B. Tied Ridges.

Ridges are small rectangular basin-like structures formed within the furrows of cultivated land to help the soil retain more water. The use of tied ridges helps in increasing soil water in the rhizosphere by 30% compared to non-ridge sites. Reduce soil water erosion thus giving time for the rainwater to infiltrate and also increase moisture retention. The retained soil water in the ridges provides enough moisture to the plants and therefore improves crop productivity by generally improving water use efficiency.

C. Combined Use of Organic and Inorganic Fertilizers.

Integration of organic and inorganic fertilizers combined with soil and water conservation measures has resulted in increased soil fertility and improved crop productivity. Combining organic and mineral (inorganic) fertilizers can be utilized to boost crop output and nutrient utilization efficiency. This strategy increases the soil's physiochemical and biological conditions which enhances the environment for crop growth hence high yield productivity. Combined use of organic and mineral fertilizers has also been identified as a water saving strategy since they improve the soil structure thus increasing infiltration and minimizing surface runoff.

D. Minimum Tillage with Mulch.

Minimum tillage is defined as a soil conservation system where agronomic practices are applied with very minimal soil disturbance. The main goal of minimum tillage is to reduce land manipulation by reducing soil disturbances. In contrast to intensive tillage whereby soil nutrients are being washed of the farming land, minimum tillage retains the bare ground cover that immensely adds to the reservoir of soil organic matter. Through minimal land tillage, the undisturbed soil ground cover decreases soil erosion since the soils are less exposed to erosive forces such as runoff water or wind.

1.2. Socio-economic and biophysical challenges

Understanding and addressing these challenges is crucial for successful implementation and adoption of ISFM practices: Addressing socio-economic and biophysical challenges requires a multi-dimensional approach involving government support, policy interventions, research and development, extension services, capacity building, and collaboration among stakeholders. Public-private partnerships, farmer cooperatives, and community-based organizations can play a vital role in promoting ISFM practices and overcoming these challenges.

1.2.1. Socio-economic Challenges

- Farmers may face challenges in accessing necessary resources for ISFM, such as organic materials, mineral fertilizers, improved seeds, and mechanization. Limited access can be due to factors such as high costs, lack of availability, inadequate infrastructure, or poor market linkages.
- Farmers may have limited awareness and knowledge about ISFM practices, their benefits, and how to implement them effectively. Insufficient extension services, limited training opportunities, and low literacy levels can contribute to this challenge.
- Implementing ISFM practices often requires upfront investments, such as purchasing inputs and equipment. Farmers with limited financial resources may find it challenging to afford these investments.

1.2.2. Biophysical Challenges

- Variability in terms of fertility, pH, texture, and nutrient content. This variability poses challenges in designing site-specific ISFM approaches.
- Changing weather patterns, increased temperatures, and irregular rainfall can affect the timing and effectiveness of ISFM practices. Climate-smart ISFM approaches, such as water management, conservation agriculture, and agroforestry, can help mitigate these challenges.

- The emergence of new pests and diseases, as well as the development of resistance to pesticides, can pose challenges. Integrated approaches, including biological control, crop rotation, and resistant varieties, are important for effective pest and disease management.
- Soil erosion, degradation and loss of soil fertility are common challenges in many agricultural landscapes. Implementing soil conservation measures, such as contour plowing, terracing, and cover cropping, can help mitigate erosion and maintain soil quality.

1.3. Local adaptation of requiring ISFM practices

Local adaptation of ISFM practices ensures they are contextually relevant, feasible and acceptable to farmers. It also strengthens local ownership and empowers communities to manage their soil fertility sustainably. Collaboration among stakeholders, including government agencies, research institutions, NGOs and farmers' organizations is essential for successful local adaptation and widespread adoption of ISFM practices.

Considerations for adapting ISFM practices at the local level:

- Understand the local agroecological conditions, including soil types, climate, cropping systems, and socio-economic factors.
- Involve local farmers, communities, and stakeholders in the planning and decision-making processes. Seek their input, knowledge and experience to ensure that ISFM practices align with their needs, preferences, and resources.
- Provide training and extension services to farmers on ISFM practices. This includes sharing information on the benefits, techniques and implementation strategies.
- Identify and utilize locally available resources for soil fertility management. This may include organic materials like crop residues, animal manure, compost, or locally available mineral sources.
- Select appropriate crop species and varieties that are well-adapted to the local conditions and have high nutrient use efficiency.
- Establish platforms for sharing information, experiences, and best practices among farmers, researchers and extension services. Encourage farmer to farmer knowledge

exchange, field demonstrations and learning network. This facilitates continuous learning, adaptation, and improvement of ISFM practices.

- Develop systems for monitoring and evaluating the adoption and impact of ISFM practices at the local level. Collect data on crop yields, soil fertility indicators, farmers' perceptions, and economic outcome.

Self-check 1	Written test

Directions: Answer all the questions listed below.

Part I. write true if the statement is correct false if not

1. The selection of an appropriate ISFM strategy should consider the soil's pH level and the need for pH adjustment.
2. The selection of an appropriate ISFM strategy should take into account the availability and accessibility of organic amendments, such as compost or manure.
3. The selection of an appropriate ISFM strategy should consider the presence of specific soil constraints, such as salinity or waterlogging.
4. The selection of an appropriate ISFM strategy should consider the local climate and rainfall patterns in order to optimize nutrient management and minimize nutrient losses.

Part II. Choose the correct answer from the following alternatives

1. Which Integrated Soil Fertility Management (ISFM) strategy is most suitable for improving soil fertility in acidic soils with low organic matter content?
    a) Cover cropping and green manure
    b) Application of lime and organic amendments
    c) Precision nutrient management
    d) Crop rotation and diversification
2. In a region with high rainfall and leaching potential, which ISFM strategy would be effective in preventing nutrient runoff and ensuring sustainable soil fertility?
    a) Agroforestry
    b) Conservation tillage
    c) Integrated use of chemical fertilizers and organic inputs
    d) Vermicomposting
3. What ISFM approach is best suited for addressing nutrient deficiencies in soils with a history of excessive fertilizer use, aiming for balanced nutrient management?
    a) Site-specific nutrient management
    b) Legume intercropping
    c) Mulching and residue management

d) Crop rotation with nitrogen-fixing crops

4. Which ISFM strategy is most appropriate for improving soil fertility in sandy soils with poor water-holding capacity?
    a) Application of gypsum
    b) Irrigation with treated wastewater
    c) Use of cover crops with deep root systems
    d) Intercropping with nitrogen-fixing plants
5. In a region facing the challenge of soil erosion, which combination of ISFM practices would be effective in promoting sustainable soil fertility and preventing further erosion?
    a) Contour plowing and agroforestry
    b) No-till farming and precision nutrient management
    c) Organic amendments and crop diversification
    d) Rotational grazing and green manure cover crops

Part III: Short Answer Questions

1. Why is it important to select an appropriate Integrated Soil Fertility Management (ISFM) strategy?
2. What are the key considerations when choosing an ISFM strategy for a specific agricultural system?
3. What are some common ISFM practices that can improve soil fertility and nutrient management?
4. Explain the importance of crop rotation and diversification in an ISFM strategy.
5. How can organic matter management contribute to soil fertility improvement in an ISFM approach?
6. What role does the application of organic and inorganic fertilizers play in an ISFM strategy?

Operation Sheet 1: Integrated Application of organic and inorganic fertilizer with soil amendments

Objective: To optimize soil fertility through the combined use of organic and inorganic fertilizers with soil amendments for improved crop yield.

Equipment and Materials:

- Organic fertilizers (e.g., compost, manure, biofertilizers)
- Inorganic fertilizers (e.g., nitrogen, phosphorus, potassium fertilizers)
- Soil amendments (e.g., lime, gypsum, organic matter)
- Fertilizer spreaders or applicators
- Soil testing kit or laboratory services
- Plant nutrient requirements guidelines
- Calculators or measuring tools for accurate application rates
- Personal protective equipment (PPE)

Procedures:

Step 1: soil assessment

- Conduct a comprehensive soil test to determine baseline nutrient levels, pH, and organic matter content.
- Analyze soil texture and structure to identify potential compaction issues.

Step 2: crop nutrient requirements

- Refer to crop-specific nutrient requirements based on growth stages and local agronomic recommendations.
- Determine the ratio of organic to inorganic fertilizer needed for balanced nutrient application.

Step 3: selection of fertilizers and amendments

- Choose organic fertilizers based on nutrient content, availability, and compatibility with the chosen crops.
- Select appropriate inorganic fertilizers considering the specific nutrient deficiencies identified in the soil test.
- Identify suitable soil amendments (e.g., lime, gypsum) based on pH and nutrient requirements.

Step 4: application rates and timing

- Calculate the precise application rates for both organic and inorganic fertilizers, ensuring adherence to recommended nutrient levels.
- Plan application timings, considering the crop's growth stages and seasonal nutrient demand.

Step 5: application methods

- Implement proper application methods, such as broadcasting, banding, or side dressing, to ensure even distribution.
- Incorporate organic fertilizers into the soil to promote microbial activity and nutrient release.
- Consider split applications for inorganic fertilizers to match nutrient availability with crop needs.

Step 6: record keeping

- Maintain detailed records of the type and quantity of fertilizers used, application dates, and any observed changes in soil conditions.
- Document any unexpected challenges or adjustments made during the application process.

Step 7: monitoring and evaluation

- Periodically monitor crop growth and health throughout the season.
- Conduct additional soil tests as needed to assess the effectiveness of the integrated fertilizer application.
- Evaluate crop yield and quality against expected outcomes

https://www.youtube.com/watch?v=3HIYPdqaP8s

https://www.youtube.com/watch?v=LdR7eyXNqCs

LAP test -1

Name……. ID……..

Date…….

Time started: _____ Time finished: _____

Instructions: Given necessary templates, tools and materials you are required to perform the following task within **1** hour. The project is expected from each student to do it.

Task 1: You are required to perform integrated application of organic and inorganic fertilizer with soil amendments

LG #2	LO #2: Determine relevant soil health and fertility management technologies

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics:

- Definition of Goals and target site
- Accessing and reviewing relevant data
- Determining, implementing and monitoring soil, plant and water tests
- Characteristics and nutritional status of soils and plant species
- Integrated soil fertility technologies

This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Define the Goals and target site
- Access and reviewing relevant data
- Determine, implement and monitor soil, plant and water tests
- Identify characteristics and nutritional status of soils and plant species
- Apply integrated soil fertility technologies

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below.
3. Read the information written in the information Sheets
4. Accomplish the Self-checks
5. Perform Operation Sheets
6. Do the “LAP test”

Information Sheet 2

2.1. Definition of Goals and target site

The goals of determining relevant soil health and fertility management technologies are to identify and implement practices that improve soil health, enhance nutrient availability, and optimize crop productivity. This involves assessing the specific needs of the soil and tailoring management strategies accordingly.

The target site refers to the specific agricultural location or field where the soil health and fertility management practices will be implemented. It could be a single farm, a specific plot or field, or a designated area within a larger agricultural landscape.

The goals of determining relevant soil health and fertility management technologies are achieved by:

- Setting clear objectives for soil health and fertility improvement, such as increasing nutrient availability, enhancing soil structure, reducing soil erosion, or promoting beneficial microbial activity.
- Evaluating a range of soil health and fertility management technologies and selecting those that are most suitable for addressing the identified constraints and achieving the defined objectives.
- Prioritizing practices that promote sustainability such as organic farming techniques, conservation agriculture, integrated nutrient management, and water-efficient irrigation methods.
- Considering site-specific factors like climate, soil type, crop rotation, and cropping systems to ensure the chosen technologies are well-suited to the target site's unique conditions.

2.2. Access and review relevant data

It is an essential step in determining relevant soil health and fertility management technologies. By analyzing available data, farmers can make informed decisions about the most suitable practices for their specific agricultural systems.

- Review historical crop performance data, including yield records, pest and disease incidence, and overall crop health. This information helps identify patterns or trends that may indicate specific soil health or fertility issues.
- Access climate and environmental data for the target site, such as rainfall patterns, temperature fluctuations, and soil moisture levels.
- Consult with local agricultural experts, extension services, or experienced farmers in the area.

2.3. Determine, implement and monitor soil, plant and water tests

2.3. 1. Determine, implement and monitor Soil

2.3.1.1. Determine soil pH

Soil pH refers to the acidity or alkalinity of the soil. It is a measure of the concentration of free hydrogen ions (H^+) and hydroxide ions (OH^-) that are in the soil. Soil pH is directly related to base saturation; as base saturation increases, so dose pH. pH influences nutrient availability, soil physical condition and plant growth. Optimum pH range for availability of different nutrients:

Nutrient	Optimum pH Range
N	6.0-8.0
P	6.5-7.5
K	6.0-7.5
S	6.0 and above
Ca & Mg	7.0-8.5
Fe	6.0 and below
Mn	5.0-6.5
Bo, Cu, Zn	5.0-7.0
Mo	7.0 and above

Principle: The pH value of an aqueous solution is the negative logarithm of hydrogen concentration. Ion activity is measured by using a pH meter. Soil pH is determined in 1:2.5 soil/water extract.

Reagent: Standard pH solutions with values 2, 4, 7, 9.2

Apparatus:

- pH meter.
- Beaker 50 ml.
- Glass rods.
- Thermometer.

Procedure:

Extraction:

- Add 25 ml distilled water to 10 g air-dried sample in a beaker 50 ml. Read the suspension temperature by thermometer.
- Stir at regular intervals for 20-30 minutes.
- Wash the pH meter electrode with distilled water.
- Open the contact switch, wait 5 minutes, adjust temperature knob to room temperature.

Calibration:

- Rinse the electrode and adjust the pH dial with a standard pH solution followed by another acid or alkaline one.

Measurement:

- Rinse the electrode with distilled water, then with the soil suspension after stirring.
- Read the pH value of the soil suspension.

2.3.1.2. Determining cation exchange capacity

Cation exchange capacity (CEC) is a fundamental soil property used to predict plant nutrient availability and retention in the soil. It is the *potential* of available nutrient supply, not a direct measurement of available nutrients. Soil CEC typically increases as clay content and organic matter increase because cation exchange occurs on surfaces of clay minerals, organic matter, and roots.

Table1. The relationship between soil texture and CEC

Soil Texture	Typical CEC (meq/100 g soil)
Sands	3-5
Loams	10-15
Silt loams	15-25
Clay and clay loams	20-50
Organic soils	50-100

CEC is defined as a soil's total quantity of negative surface charges. It is measured commonly in commercial soil testing labs by summing cations (positively charged ions that are attracted to the negative surface charges in soil). Exchangeable cations include base cations, Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}, as well as acid cations such as H^{+}, Al^{3+} and (NH_4^{+}).

CEC = *Base cations* + Acid cations

(Ca^{2+} + Mg^{2+} + K^{+} + Na^{+}) + (H^{+} + Al^{3+} + NH_4^{+})

Base saturation

Base saturation is calculated as the percentage of CEC occupied by base cations. Base saturation is closely related to pH; as base saturation increases, pH increases.

Base Saturation (%) = (*Base cations/CEC*) x 100

Similarly, we can calculate the base saturation for each individual base cation. Calcium base saturation is calculated as the percentage of CEC occupied by calcium cations. In Figure 2, the soil on the right has twice as many calcium cations (Ca^{2+}), thus higher calcium saturation.

Calcium Saturation (%) = (*Calcium cations/CEC*) x 100

Calculating CEC from a Soil Test

CEC is reported as milliequivalents per 100 grams of soil (meq/100g), or charge per weight of soil. Milliequivalents are used instead of weight because charge is more useful when talking about ion exchange.

So, how do we take the concentration of nutrients in a soil test (ppm) and convert to charges (meq/100g soil)? Soil testing laboratories often provide these values already on the soil test report, or will provide them upon request. However, to gain a better understanding of the relationships, the steps to perform these calculations are outlined below.

Step 1: Determine the gram equivalent weight of each base cation**.** Each base cation has an atomic weight and valence number (charge) in the periodic table of elements.
For calcium, the atomic weight is ~40 grams per mole and the charge is 2. We divide each atomic weight (40) by the charge (2) to calculate the gram equivalent weight (20). The value for each base cation is outlined in Table 2.
Step 2: Convert gram equivalent weight into charge per weight of soil (meq/100g soil).

$$\text{equivalent} \times \frac{1000 \text{ milliequivalent}}{1 \text{ equivalent}} \times \frac{1}{100 \text{ g soil}} = \frac{10 \text{ meq}}{\text{g soil}}$$

Step 3: Multiply the gram equivalent weight by 10 to convert to meq/100g of soil. Again, for calcium, the gram equivalent weight of 20 grams multiplied by 10 gives us 200 meq/100 g soils. This meq/100g soil value is used as a conversion factor for the nutrient concentration values (ppm) received in a soil test. The bolded values in the last column in Table 2 can be used as a conversion factor each time and will not change.

Table 2. The meq/100g soil constants for the base cations Ca, Mg, K, and Na.

Base Cation	Atomic Weight	Charge (Valence)	Gram Equivalent Weight (g)	Milliequivalent/ 100 g soil
Calcium (Ca)	40	2	20	**200**
Magnesium (Mg)	24	2	12	**120**
Potassium (K)	39	1	39	**390**
Sodium (Na)	23	1	23	**230**

Step 4: Convert soil test nutrient concentration to charge. Table 3 provides an example of typical soil test levels in Ohio (in ppm). We can calculate the collective charge each cation occupies on the exchange sites by taking the values calculated in Table 2 (last column) and dividing them by the soil test levels. For calcium, a soil test level of 2000 ppm, divided by 200 equals 10.0 meq/100 g soil. This is done for each cation individually.

Step5: Calculate collective charge from base cations. Next, we add up the charges of each base cation. For this example, the sum of base cations equals 12.4 meq/100g soil (Table 3).

Step 6: Calculate exchangeable acidity, using the buffer pH with the empirically derived conversion equation (Table 3). If the soil has a pH greater than 7.0, you essentially have no exchangeable acidity and CEC is just the sum of base cations. A soil with a buffer pH of 6.6 indicates that acidic cations occupy 4.8 meq per 100 grams of soil.

Table3: Conversion of soil test values (ppm) to meq/100 g soil for base and acid cations to determine CEC.

Base Cation	Soil test level (ppm)	Milliequivalent/ 100 g soil	meq/100 g soil
Calcium (Ca^{2+})	2000	200	10.0
Magnesium (Mg^{2+})	240	120	2.0
Potassium (K^{+})	100	390	0.26
Sodium (Na^{+})	20	230	0.09
Subtotal			**12.4**

Acid Cation	Buffer pH	Conversion Equation	meq/ 100 g soil
Exchangeable acidity (H^{+}, Al_3^{+}, NH_4^{+})	6.6	12 x (7.0 – 6.6)	**4.8**

*If soil test values are in pound per acre, then first convert pound per acre to ppm by dividing soil test values by 2.

**If buffer pH is 7 or above, then you have no exchangeable acidity (CEC = sum of base cations).

Step7. Calculate CEC by adding the base cations and acid cations:

Cation exchange capacity (CEC) = *Base cations* + Acid cations

=12.4 + 4.8=12.4 + 4.8

= 17.2 *meq*/100 *g*

With CEC, we can calculate the following (multiplying by 100 to get a percentage):

Base Saturation (%) = (*Base cations/CEC*) x 100 x 100

= (*12.4*/17.2) x 100 x 100

= 72%

Calcium Saturation (%) = (*Calcium cations/CEC*) x 100

= (*10*/17.2) x 100 x 100

= 58**%**

Magnesium Saturation (%) = (*Magnesium cations/CEC*) x 100 x 100

= (*2.0*/17.2) x 100 x 100

= 12%

To determine Cation Exchange Capacity

Apparatus

- Flame photometer.
- Mechanical shaker, reciprocating.
- Centrifuge, capable of 3000 rmp.
- Conical centrifuge tubes (50 mL)

Reagents

A. Sodium Acetate Solution (NaOAc), l N ' Dissolve 136 g sodium acetate trihydrate ($CH_3COONa.3H_2O$) in about 950 mL DI water, mix well, and 1et the mixture cool. ‘Adjust pH to 8.2 by adding more acetic acid or sodium hydroxide, and bring to 1-L volume with DI water.

B. Ethanol (C_2H_5OH), 95%

C. Ammonium Acetate Solution (NH_4OAc), lN ' Add 57 mL concentrated acetic acid (CH3COOH) to 800 mL DI water, then add 68 mL concentrated ammonium hydroxide (NH_4OH), mix well, and let the mixture cool. ‘Adjust to pH 7.0 by adding more acetic acid or ammonium hydroxide, and bring to 1-L vo1ume with DI water.

D. Standard Stock Solution ' Dry about 5 g sodium chloride (NaCl) in an oven at 105ºC for 3 hours, cool in a desiccator, and store in a tightly stoppered bottle. ‘Dissolve 2.5418 g dried sodium chloride in DI water, and brings to 1-L volume with DI water. This solution contains 1000 ppm Na (Stock Solution). ' Prepare a series of Standard Solutions from the Stock Solution as follows: Dilute 2, 4, 6, 8, 10, 15, and 20 mL Stock Solutions to 100 mL final volume by adding 1 N ammonium acetate solution, and 25 mL LiCl (Diluted Stock Solution). These solutions contain 20, 40, 60, 80, 100, 150, and 200 ppm Na, with each containing the same concentration of LiCl (25 ppm).

Procedure

i. Weigh 4 g (for medium to fine textured) or 6 g (for coarse textured) air-dry soil into a 40-mL centrifuge tube, and add 33 mL 1 N sodium acetate trihydrate solution, stopper tube, and shake for 5 minutes.

ii. Remove stopper from tube and centrifuge at 3000 rpm until supernatant liquid is clear. Decant the supernatant as completely as possible and discard.

iii. Repeat with 33-mL portions 1 N sodium acetate trihydrate solution, a total of four times, discarding the supernatant liquid each time. Then add 33-mL 95% ethanol, stopper tube, and shake for 5 minutes, unstop per tube, and centrifuge until the supernatant is clear and decant.

iv. Wash the sample with 33 mL portions 95% ethanol, a total of three times, discarding the supernatant liquid each time. The electrical conductivity (EC) of the supernatant liquid from the third washing should be less than 400 µS/cm.

v. Replace the adsorbed sodium (Na^+) from the sample by extraction with three 33-mL portions 1 N ammonium acetate solution. Each time shake for 5 minutes, and centrifuge until supernatant liquid is clear.

vi. Decant the three supernatant liquids as completely as possible into a 100-mL volumetric flask, bring to volume with 1 N ammonium acetate solution, and mix well.

vii. Run a series of suitable Na standards, and draw a calibration curve.

viii. Measure the samples (soil extract) and take the emission readings by a Flame Photometer.

ix. Calculate sodium (Na) concentration according to the calibration curve.

Calculation:

For Cation Exchange Capacity in soil:

$$\text{CEC (meq/100 g)} = \text{meq/L Na (from calibration curve)} \times \frac{A}{Wt} \times \frac{100}{1000}$$

Where: A = Total volume of the extract (mL)
Wt = Weight of the air-dry soi1 (g)

2.3.1.3 Determine nutrient and carbonate content

Determination of calcium carbonate

Amount of calcium carbonate in soil indicates one of the most important soil properties. In this method it is determined volumetrically by measuring the CO_2 volume evolved from the reaction of hydrochloric acid with soil carbonate.

Reagents:

- Commercial hydrochloric acid: 1: 3.
- 105 ^oC. dried calcium carbonate.
- Potassium bichromate 1 N.

Apparatus:

- Calcimeter.
- Thermometer.

Procedure:

Calibration:

i. Fill the graduated tubes with potassium bichromate and adjust the upper level in both tubes equally.

ii. Put 0.10 gm oven-dried $CaCO_3$ in the vail and inserted in an upright position in the reaction flask containing 10 ml of HCL 1:3 after mixing 22.4 cm^3 CO_2 are evolved under the conditions of the standard temperature and pressure.

Measurement:

i. A weight of 1 g air dried soil sample is transferred into a plastic vial and inserted in an upright position in the reaction flask containing 10 ml of HCL 1: 3.

ii. Mix.

iii. Record the difference of potassium bichromate volume, due to evolved CO_2 gas pressure in the graduated upper tubes.

iv. Record room temperature.

v. Correct the volume of CO_2 for the standard temperature and pressure. Then milligrames of soil carbonates as $CaCO_3$ can be calculated.

Calculation:

$$CaCO_3\ \% = \frac{volume\ of\ CO_2\ (cm^3) \times 273 \times 100 \times 100 \times 10}{1000 \times (273 + temperature) \times 224 \times 1}$$

$CaCO_3$ % can be calculated directly using the attached table as follows:

$$\%\ CaCO_3 = \text{volume of } CO_2 \times \text{Factor.}$$

Determine total Nitrogen

Principle: Organic and nitrate nitrogen is converted to ammonium sulphate and the ammonium is distilled into boric acid and titrated with HCL or H_2SO_4 using appropriate indicator.

Reagents:

- Digestion mixture:
- Potassuin sulphate K_2SO_4.
- Copper sulphate $CuSO_4$. $5H_2O$.
- Selenium. A,b,c are mixed with proportion of 10 : 1 : 0.5 respectively.
- H_2SO_4 conc.
- NaOH solution (40%).
- H_3BO_3 solution (4%).
- 0.01 N HCL
- Tashiro's indicator (0.248 g methylene blue and 0.375 g methyl red dissolved in 300 ml ethyl alcohol absolute, Allen, 1953).

Apparatus:

- Micro-kjeldahl distillation apparatus.
- Erlenmeyer flasks 100 ml.
- Kjeldahl digestion flasks (or conical flask) 500 ml.
- Test tubes.
- Automatic burettes.
- Pipette 10 ml (one pulp).
- Measuring flask 250 ml.

Procedure:

Digestion:

i Weigh 5 g soil into digestion flask.

ii Add 5 g digestion mixture and 20 ml H_2SO_4 conc.

iii Put the flask on digestion board with electric heaters. Heat gradually; low at 10-30 minutes, then raise heating degree.

iv After the end of fuming, the digestion is continued for 1 hour after the solution had cleared with white color of digestion mixture.

v Transfer the sample to 250 ml volumetric flask; complete the volume with dist. Water.
Distillation:

vi Put 20 ml H_3BO_3 in Erlenmeyer flask and 4 drops of the indicator. Put the flask so that the lower tip of the glass receiver tube is below the boric acid surface.

vii Start running the cooling water in condenser

viii Start boiling the water in the boilers.

ix Put 25 ml of the sample in the funnel with dist. Water. Released ammonia is trapped in boric acid.

Titration:
10- Ammonia is titrated with HCL or H_2SO_4. At end point the green color just disappears.

Calculation:

$$\text{N \% in soil} = \frac{(Sample\ titration - Blank) \times noramlity \times 14 \times dilution}{sample\ weight}$$

$$= \frac{S - B \times \frac{14}{100} \times \frac{250}{50} \times \frac{1000}{5}}{10{,}000}$$

Determine available Phosphorus

Many tests for determining the so called “available" phosphorus in soils have been in use for many years. The sodium bicarbonate method of Olsen et al. (1954) has given better correlation with field responses to phosphate fertilizers on both acid and alkaline soils than many of the other methods. For that reason, the details of this method are outlined here.

Extraction from soil: Sodium Bicarbonate Method.

Principle: This method extracts some of the exchangeable or surface absorbed phosphorus of soils, some of the calcium phosphates and other phosphates, and has given a good correlation with field responses. The soil is extracted with 0.5 M sodium bicarbonate and the phosphate extracted is determined calorimetrically.

Reagents: Sodium bicarbonate, 0.5 N (pH 8.5):

i Dissolve 42.0 g Na HCO_3 in about 900 ml of distilled water.

ii Adjust to pH 8.5 with Na OH (50%) and make to 1 L volume with distilled water.

iii Add mineral oil and avoid exposure to air.

Apparatus:

- Shaker
- Beakers
- Cylinder 100 ml.,
- Funnels and filter paper.

Procedure:

i 5 g air-dried soil (passed through 1-2 mm sieve) is suspended in 100 ml of Na HCO_3 extraction solution.

ii The suspension is shaken for a period of 30 minutes.

iii The solution is filtrated through a whatman 40 or other suitable filter paper. Determination: The concentration of phosphorus in the filtrate is determined by one of the following methods: Micro-Vanadate-Molybdate method:

Principle: This method is sensitive to 20-200/ug p/50 ml. The developed yellow color is stable for 6 hours at least.

Reagents:

1- Solution (1): 25 g ammonium molybdate in 400 ml dist. H_2O.

Solution (2): 1.25 g of ammonium metavandate in 300 ml of boiling dist. H_2O.

Solution (2): is cooled and then 250 ml of concentrated HNO_3 is added and the solution is again cooled to room temperature. Finally solution 1 is poured into solution 2 and the mixture is diluted 1 litre. The solutions are mixed at a ratio of 1:1:1. 2- Potassium dihydrogen phosphate (500 ppm P): Dissolve 2.197 grams dried KH_2PO_4 in 1 L distilled water. A dilute standard

solution is prepared for making up a series of standards for the calibration curve, from 0.2 ppm to 2.5 ppm.

Apparatus:

Spectrophotometer

Procedure:

i 35 ml of soil extract is transferred to a 50 ml volumetric flask.

ii 10 ml of the vanadate solution are added and make the volume to 50 ml with distilled water.

iii After 10 minutes read at 405 nm by using spectrophotometer.

Calculation:

$$\text{P mg/100g} = \frac{Reading \times factor}{10} \times \frac{100}{dry\ weight\ at\ 105^{o}C}$$

Determine Potassium, Sodium and Magnesium

Extraction from soil: by ammonium acetate method.

Principle:

Ammonium acetate is known to extract the soil exchangeable potassium among other cations. This is rapid procedure for extraction of potassium separately from other exchangeable metallic cations. Potassium adsorbed on the soil a particle is exchanged with ammonium of the acetate solution, maximally at the latter's strength. Sodium and magnesium could be also extracted by the same reagent.

Apparatus: Shaker, plastic bottle with caps, cylinder, beaker.

Reagents:

Ammonium acetate 1 N: To 700 – 800 ml distilled water, add 57 ml. conc. acetic acid + 68 ml of conc. ammonium hydroxide. Dilute to a volume of 1 liter and adjust to pH 7.0 by the addition of more ammonium hydroxide or acetic acid. The same solution can be also made by dissolving 77 g ammonium acetate in 1 liter dist. Water.

Procedures:

i Add 100 ml of ammonium acetate solution to 5 g air dried soil (passed through 1-2 mm sieve) in a plastic bottle. Place the bottles in the shaker.

ii Shake for 1 hour.

iii Filtrate through filter paper what man 41 or S & S 512; M & N 280. Receive in a plastic container. Discard the first third of the filtrate.

Determine of Potassium and sodium

Principles: Potassium and sodium ions can be determined quantitatively when they are atomized from solution, led to burner and exited to spectral emission in a flame. Since the intensity of the light emitted by each element depends primarily on the concentration of its atoms in the flame at any given instant, a measurement of the light intensity produced by a given element makes possible the quantitative determination of that element.

Apparatus:

Flame photometer: Potassium chloride 1000 ppm: Dissolve 1.9117 g dried KCl in distilled water and make to 1 L volume. - Sodium chloride 1000 ppm: Dissolve 2.5422 g dried NaCl in distilled water and make to 1 L volume. Standard curve solutions: Prepare the following dilution 10, 20, 30, …….., 100 ppm from the standard 1000 ppm solution in solution of 1 N ammonium acetate pH 7.0.

Procedure:

i Pipet an aliquot of the solution to be analyzed into a 50 ml volumetric flask, complete with 1 N ammonium-acetate solution (pH 7).

ii Determine the potassium concentration by use of the flame photometer and the appropriate calibration curve.

Terminating operations:

i Introduce distilled water for approximately 3 minutes to clean the intake and the atomizer/burner assembly.

ii Close the valve of supplying gas.

iii Push down button of gas selection and wait until the flame is extinguished.

iv Switch off main switch.

v Place cover over the housing after allowing sufficient time for cooling off.

Calculation:

- Concentration of K or Na in sample-extract can be calculated by slope calculation. For every concentration of the standard solution (10-100 ppm) the concentration is divided by the reading of the apparatus. Mean of the resulting values is the slope.
- Content of K and Na in soil sample: Content of K or Na as mg/100g soil (at 105 ^{o} C) 1.11 – Magnesium: Magnesium can be determined by atomic adsorption.

  Reagents: Standard stock solution 1000 ppm. A dilute standard solution is prepared for making up a series of standards for the calibration curve, from 0.1 to 8 ppm.

2.3.1.4 Determination of soil salinity

Water and soil salinity are measured by passing an electric current between the two electrodes of a salinity meter in a sample of soil or water. The electrical conductivity or EC of a soil or water sample is influenced by the concentration and composition of dissolved salts.

Effects of Salinity on Plant Growth

Salinity reduces water availability for plant use. High salt levels hinder water absorption, inducing physiological drought in the plant. The soil may contain adequate water, but plant roots are unable to absorb the water due to unfavorable osmotic pressure. This is referred to as the osmotic or water-deficit effect of salinity. Plants are generally most sensitive to salinity during germination and early growth.

The second effect of salinity is shown when excessive amounts of salt enter the plant in the transpiration stream and injure leaf cells, which further reduces growth. This is called the salt-specific or ion-excess effect of salinity. Symptoms may include restricted root growth, marginal or leaf tip burning/browning, inhibited flowering, reduced vigor and reduced crop yields.

Visual Diagnosis of Salt-Affected Soils

Accumulation of salts can result in three soil conditions: saline, saline-sodic and sodic soils. Each of these soil conditions has distinct characteristics that can be observed in the field, which are useful for diagnosing the problem. Completely white soils are saline, soils with a brownish-

black crust are sodic, and grey-colored soils are generally saline-sodic. The following physical observations/symptoms may be helpful in diagnosing saltrelated soil problems:

Problem	Symptoms
Saline	White crust on soil surface. Water-stressed plants. Leaf tip burn.
Sodic	Poor drainage. Black powdery residue on soil surface.
Saline-Sodic	Grey-colored soil. Plants showing water stress.
Source: Waskom et al., 2010. Diagnosing saline and sodic soil problems. Colorado State University Extension Fact Sheet # 0.521	

Soil Salinity Measurements

Problems due to soil salinity and sodicity in soil are commonly evaluated by laboratory testing. The following laboratory measurements are typically used to determine the extent of these problems:

A. Electrical Conductivity (EC):

Measures the ability of the soil solution to conduct electricity and is expressed in decisiemens per meter (dS/m, which is equivalent to mmhos/cm). Because pure water is a poor conductor of electricity, increases in soluble salts result in proportional increases in the solution EC. The standard procedure for salinity testing is to measure EC of a solution extracted from a soil wetted to a “saturation paste. a saline soil has an EC of the saturated paste extract of more than 4 dS/m, a value that corresponds to approximately 40 mmol salts per liter. Crops vary in their tolerance to salinity and some may be adversely affected at ECs less than 4 dS/m. Salt tolerances are known for common crops. For example, peach is sensitive, whereas cotton is more salt tolerant. Beets and asparagus are very tolerant of salinity.

B. Total Soluble Salts (TSS):

IT refers to the total amount of soluble salts in a soil-saturated paste extract expressed in parts per million or milligrams per liter (ppm or mg/L). A linear relationship exists between TSS and EC within a certain range that can be useful to closely estimate soluble salts in a soil solution or extract. The ratio of TSS to EC of various salt solutions ranges from 550 to 700 ppm per dS/m. Sodium chloride, the most common salt, has a TSS of 640 ppm per dS/m. So if EC is known, TSS can be estimated using the formula below:

$TSS\ (mg/L\ or\ ppm) = EC\ (mmhos/cm\ or\ dS/m) \times 640$

C. Sodium Adsorption Ratio (SAR):

It is a widely accepted index for characterizing soil sodicity, which describes the proportion of sodium to calcium and magnesium in soil solution. The formula to calculate SAR is given below, with concentrations expressed in milliequivalents per liter (meq/L) analyzed from a saturated paste soil extract.

$$SAR = \frac{[Na^+]}{\sqrt{1/2\ ([Ca^{2+}] + [Mg^{2+}])}}$$

When SAR is greater than 13, the soil is called a sodic soil. Excess sodium in sodic soils causes soil particles to repel each other, preventing the formation of soil aggregates. This results in a very tight soil structure with poor water infiltration, poor aeration and surface crusting, which makes tillage difficult and restricts seedling emergence and root growth.

D. Exchangeable Sodium Percentage (ESP):

It is another index that characterizes soil sodicity. As noted above, excess sodium causes poor water movement and poor aeration. By definition, sodic soil has an ESP greater than 15. ESP is the sodium adsorbed on soil particles as a percentage of the Cation Exchange Capacity (CEC). It is calculated as:

$$ESP = \frac{[Na^+]}{CEC} \times 100$$

CEC is often estimated as the sum of the major exchangeable cations, including hydrogen. Both cations and CEC are expressed as meq/100g. ESP can also be calculated as:

$$ESP = \frac{[Na^+]}{[Ca^{2+} + Mg^{2+} + Na^+ + K^+]} \times 100$$

ESP is used to characterize the sodicity of soils only, whereas SAR is applicable to both soil and soil solution or irrigation water.

The Natural Resources Conservation Service (NRCS) provides the following classification of salt-affected soils using the saturated paste extraction:

Class	EC (mmhos/cm)	SAR	ESP	Typical soil structural condition*
Normal	Below 4.0	Below 13	Below 15	Flocculated
Saline	Above 4.0	Below 13	Below 15	Flocculated
Sodic	Below 4.0	Above 13	Above 15	Dispersed
Saline-Sodic	Above 4.0	Above 13	Above 15	Flocculated
*Soil structural condition also depends on other factors not included in the NRCS classification system, including soil organic matter, soil texture and EC of irrigation water (Horneck et al., 2007).				

2.3.1.5 Determine soil color

Color is one of the most obvious characteristics of soil. Color can also provide a valuable insight into the soil environment and hence is very important in assessment and classification. The most influential colors in a well-drained soil are white, red, brown and black. White indicates the predominance of silica (quartz), or the presence of salts; red indicates the accumulation of iron oxide; and brown and black indicate the level and type of organic matter.

Four main factors influence the color of a soil:

- Mineral matter derived from the constituents of the parent material
- Organic matter
- The nature and abundance of iron
- Moisture content

Mineral matter: rocks are broken down to form soils, and sometimes these rocks give their color to the soil. More usually the color of the soil results from compounds such as iron.

Organic matter: humus, the final stage of organic matter breakdown is black. Throughout the stages of organic matter breakdown the color imparted to the soil varies from browns to black. Sodium content influences the depth of color of organic matter and therefore the soil. Sodium causes the organic matter (humus) to disperse more readily and spread over the soil particles, making the soil look darker (blacker).

Iron: Red, yellow, grey and bluish-grey colors result from iron in various forms. Under average conditions of air and moisture, iron forms a yellow oxide imparting a yellow color to the soil. Where soils are well draining or under dry conditions, iron forms red oxides imparting a red

color to the soil. Yet in waterlogged soil, with a lack of air, iron forms in a reduced state giving the soil grey/green/bluish-grey colors.

Water: Soil color darkens as the soil changes from dry to moist. But longer term color changes are linked to water relations as well. Careful observation of color can help to identify problems of waterlogging or leaching. Poorly drained soils are often dominated by blue grey colors often with yellow mottling. Well drained soils will usually have bright and uniform colors.

The soil colors are determined by using Munsell color chart. In this chart, different color chips are systematically arranged by three variables namely Hue, Value and Chroma.

- Hue: it indicates the dominant spectral color (red, yellow, blue and green).
- Value: it indicates lightness or darkness of a color (the amount of reflected light).
- Chroma**:** it represents the purity of the color (strength of the color).

The values are written on the left hand side and the color becomes lighter as we move upward.

- The chroma is written at the bottom and increases towards right hand side.
- The combination of these variables is used to describe the color of a soil as “Munsell notation”. The Munsell colour notations are systematic, numerical with letter designations of each of these three variables (Hue, value and chroma).
- For example, the numerical notation 2.5 YR 5/6 suggests a hue of 2.5 YR, value of 5 and chroma of 6. The equivalent or parallel soil color name for this Munsell notation is 'red'.

2.3.1.6 Determine soil organic matter

Walkley-black method

Equipment:

- 500 ml Erlenmeyer flasks.
- 10 ml pipette.
- 10 and 20 ml dispensers.
- 50 ml burette.
- Analytical balance.

- Magnetic stirrer.
- Incandescent lamp.

Reagents:

i H_3PO_4 85%

ii H_2SO_4 concentrated (96%)

iii NaF, solid

iv Standard 1.00 N $K_2Cr_2O_7$: Dissolve 49.04 g of dried (105° C) $K_2Cr_2O_7$ in water and dilute to 1 litre.

v 0.5 N Fe^{++} solution: Dissolve 196.1 g of Fe $(NH_4)2(SO_4)2$. 6 H_2O in 800 ml of water containing 20 ml of concentrated h2so4 and dilute to 1 litre. The Fe++ in this solution oxidizes slowly on exposure to air so it must be standardized against the dichromate daily.

vi Ferroin indicator: Dissolve 3.71 g of phenanthroline and 1.74 g of $FeSO_4$. $7H_2O$ in 250 ml of water.

Procedures:

i Weigh out 0.10 to 2.00 dried soil (< 60 mesh) and transfer to a 500 ml Erlenmeyer flask. The sample should contain 10 to 25 mg of organic C (17 to 43 mg organic matter). For a 1 g sample, this would be 1.2 to 4.3% organic matter. Use up to 2.0 g of sample for light colored soils and 0.1 g for organic soils.

ii Add 10 ml of 1 N$K_2Cr_2O_7$ by means of a pipette.

iii Add 200 ml of concentrated H_2SO_4 by means of dispenser and swirl gently to mix. Avoid excessive swirling that would result in organic particles adhering to the sides of the flask out of the solution.

iv Allow to stand 30 minutes. The flasks should be placed on an asbestos sheet during this time to avoid rapid loss of heat.

v Dilute the suspension with about 200 ml of water to provide a clearer suspension for viewing the endpoint.

vi Add 10 ml of 85% H_3PO_4, using a suitable dispenser, and 0.2 g of NaF, using the "calibrated spatula" technique. The H_3PO_4 and NaF are added to complex Fe^{3+}, which would interfere with the titration endpoint.

vii Add 10 drops of ferroin indicator. The indicator should be added just prior to titration to avoid deactivation of adsorption onto clay surfaces.

viii Titrate with 0.5 N Fe^{++} to a burgundy endpoint. The color of the solution at the beginning is yellow-orange to dark green, depending on the amount of the unreacted Cr^{2+} remaining, which shifts to a turbid gray before the endpoint and then changes sharply to a wine red at the endpoint.

ix Use of a magnetic stirrer with an incandescent light makes the endpoint easier to see in the turbid system. (Fluorescent lighting gives a different endpoint color). If less than 5 ml of Fe^{++} solution was required to back titrate the excess Cr^{2+}, there was insufficient Cr^{2+} present, and the analysis should be repeated either by using a smaller sample size or doubling the amount of $K_2Cr_2O_7$ and H_2SO_4. Alternatively use a Pt electrode to determine the endpoint after step 5 above. This will eliminate uncertainty in determining the endpoint by color change.

x Run a reagent blank following the above procedure without soil. The reagent blank is used to standardize the Fe^{++} solution daily.

xi Calculate % C and % organic matter:

a. % easily oxidizable organic C

$$C = \frac{(B-S) \times N \text{ of } Fe^{++}}{g \text{ of soil}} \times \frac{12}{4000} \times 100$$

Where: B = ml of Fe^{++} solution used to titrate blank,

S = ml of Fe^{++} solution used to titrate sample, and 12/ 4000 = milliequivalent weight of C in g.

To convert easily oxidizable organic C to total C, divide by 0.77 (or multiply by 1.30) or other experimentally determined correction factor.

b. % organic matter = $\frac{\%\ C}{0.58}$ = %C × 1.72

2.3.1.7 Determine soil structure

Soil structure is one of the major factors affecting crop production. Poor soil structure can limit root development, water infiltration and water availability for crop growth. Good soil structure allows water and air to move freely into the soil therefore avoiding waterlogging and run-off. Plant roots are able to explore a larger volume of soil and thus access more water and nutrients stored in the soil.

The deterioration of soil structure occurs by two processes:

- Slaking of aggregates;
- Dispersion of clay.

Slaking is defined as the rapid disintegration by pure water (e.g. rain water) of large aggregates (>2-5 mm) of soil into smaller aggregates (most of which are less than 0.25 mm). As slaked soil dries, the small aggregates settle together and create smaller soil pores than for the previous larger aggregates. Slaking occurs because of a lack of strong organic bonds between soil particles and micro-aggregates.

Dispersion is when dry soil is wet with pure water (e.g. rain water) and the clay structures that bind the fine aggregates and large particles (sand and silt) break down. The clay particles then go into suspension in the water. As the soil dries out the clay particles block the pores between the remaining aggregates. This blockage prevents the flow of water and air through the soil. Dispersion is enhanced when the soil has a high exchangeable sodium concentration, and from excessive tillage when the soil is wet.

Soil structure can be modified and improved by inputs of organic matter such as mulches, composts or cover crops. These help stabilize aggregate macro-structure. The application of gypsum to soil stabilizes aggregate micro-structure and prevents clay dispersion. Excessive tillage can break down both the macro- and microstructure of aggregates leading to hard setting and crusting of surface soils.

Equipment

There is a simple method to measure soil slaking and dispersion. You will need:

- Shallow, clear, open containers;
- Rain water or distilled water;

- A handful of soil from each soil layer being assessed;
- Recording sheet and pen.

Method

i Take three surface soil and three subsoil samples from each site as described in points 1-5 in Taking soil samples. Ensure that surface soil and subsoil are not combined so that they can be analyzed separately.

ii From each sample, select three aggregates about the size of a pea.

iii Place them carefully, equally spaced, in a shallow container filled with rain or distilled water (you can also do this test using your irrigation water if you are interested in its effect on structural stability of the soils in the vineyard).

iv Watch the aggregates closely during the first few minutes and note whether they float on the surface or sink, and the rate at which smaller particles break away from the larger sample (slaking).

v After 2 hours record whether slaking was complete, partial or absent.

vi Leave the dish untouched for 20 hours and then assess dispersion. A 'cloudy' or 'milky' halo around the slaked fragments of the aggregate indicates partial dispersion. Complete dispersion is indicated when the base of the container is completely covered with a layer of clay leaving only a pile of sand where the aggregate was placed.

vii If no dispersion occurred, take another sample from the air dried soil, remove any gravel, stones and plant fragments and moisten with rain or distilled water while kneading into a ball of about 40mm diameter. Add small amounts of water as necessary until the ball of soil just begins to stick to the hand.

viii Break the ball of soil open and remove some soil to make 3 pea size balls and place them in a clear container as described above.

ix Observe and record the results.

Interpreting results

The soil is a slaking soil if the aggregates have broken down into micro-aggregates at the end of the test period. Dispersive soils come in 4 broad types depending on the amount of dispersion as indicated below**.**

Table 2. 1: Dispersive soil types

Type 1	There has been complete dispersion such that a cloud of clay covers the bottom of the dish in a thin layer and the aggregate has almost disappeared. A small heap of sand may be left where the aggregate was placed. This type of soil is very likely to experience structural breakdown due to dispersion and will require treatment.
Type 2	There has been partial dispersion such that the dispersed clay has spread into thin streaks and crescents around the aggregate on the bottom of the container. This type of soil may experience some structural breakdown due to dispersion and could benefit from treatment.
Type 3	This soil only disperses after the clay has been worked. This means that very sound management practices can avoid crusting and erosion, but there is little room for error.
Type 4	Little dispersion occurred during the test, indicating that the aggregate structure of the soil is quite stable. The soil should not crust, and will have good rates of water entry, though it may still be susceptible to compaction.

2.3.1.8 Determine soil particle size distribution

Individual soil particles vary widely in any soil type. Similarly, as these particles are cemented together, a variety of aggregate shapes and sizes occur. For standard particle size measurement, the soil fraction that passes a 2 mm sieve is considered. Laboratory procedures normally estimate percentage of sand (0.05 - 2.0 mm), silt (0.002 - 0.05 mm), and clay (<0.002 mm) fractions in soils. Particle size distribution is an important parameter in soil classification and has implications on soil water, aeration, and nutrient availability to plants.

As primary soil particles are usually cemented together by organic matter, this has to be removed by H_2O_2 treatment. However, if substantial amounts of $CaCO_3$ are present, actual percentages of sand, silt or clay can only be determined by prior dissolution of the $CaCO_3$. The two common procedures used for particle size analysis or mechanical analysis are the hydrometer method (Bouyoucos or the pipette-gravimetric method.

The hydrometer method of silt and clay measurement relies on the effect of particle size on the differential settling velocities within a water column. Theoretically, the particles are assumed to be spherical having a specific gravity of 2.65 g/cm^3. If all other factors are constant, then the settling velocity is proportional to the square of the radius of the particle (Stoke's Law). The settling velocity is also a function of liquid temperature, viscosity and specific gravity of the

falling particle. In practice, therefore, we must know and make corrections for the temperature of the liquid. Greater temperatures result in reduced viscosity, due to liquid expansion and a more rapid descent of falling particles.

Apparatus

Soil dispersing stirrer:

A high speed electric stirrer with a cup receptacle

Hydrometer with Bouyoucos scale in g/L

Reagents

A. Dispersing Solution Dissolve 40 g sodium hexametaphosphate [$(NaPO_3)13$], and 10 g sodium carbonate (Na_2CO_3) in DI water, and bring to 1-L volume with DI water. This solution deteriorates with time and should not be kept for more than 1 to 2 weeks.

B. Amyl Alcohol

Procedure

i Weigh 40 g air-dry soil (2 mm) into a 600 mL beaker.

ii Add 60-mL dispersing solution.

iii Cover the beaker with a watch-glass, and leave overnight.

iv Quantitatively transfer contents of the beaker to a soil stirring cup, and fill the cup to about three-quarters with water.

v Stir suspension at high speed for 3 minutes using the special stirrer. Shake the suspension overnight if no stirrer is available.

vi Rinse stirring paddle into a cup, and allow to stand for 1 minute.

vii Transfer suspension quantitatively into a 1-L calibrated cylinder (hydrometer jar), and bring to volume with water.

A. Determination of Blank

- Dilute 60 mL dispersing solution to 1-L hydrometer jar with water.
- Mix well, and insert hydrometer, and take hydrometer reading, Rb.
- The blank reading must be re-determined for temperature changes of more than 2°C from 20°C. B. Determination of Silt plus Clay
- Mix suspension in the hydrometer jar, using a special paddle carefully, withdraw the paddle, and immediately insert the hydrometer.

- Disperse any froth, if needed, with one drop of amyl alcohol, and take hydrometer reading 40 seconds after withdrawing the paddle. This gives reading, Rsc.

Calculations

Percentage Silt plus Clay in soil

$$\% \text{ [Silt + Clay] (w/w)} = (R_{sc} - R_b) \times \frac{100}{\text{Oven-dry soil (g)}}$$

C. Determination of Clay

- Mix suspension in the hydrometer jar with paddle, withdraw the paddle, with great care, leaving the suspension undisturbed.
- After 4 hours, insert the hydrometer, and take hydrometer reading, RC. Percentage Clay in soil:

$$\% \text{ Clay (w/w)} = (R_c - R_b) \times \frac{100}{\text{Oven-dry soil (g)}}$$

Percentage Silt in soil:

$$\% \text{ Silt (w/w)} = [\% \text{ Silt + Clay (w/w)}] - [\% \text{ Clay (w/w)}]$$

D. Determination of Sand

- After taking readings required for clay and silt, pour suspension quantitatively through a 50 m sieve.
- Wash sieve until water passing the sieve is clear.
- Transfer the sand quantitatively from sieve to a 50 mL beaker of known weight.
- Allow the sand in the beaker to settle, and decant excess water.
- Dry beaker with sand overnight at 105°C.
- Cool in a desiccator, and re-weigh beaker with sand.

Percentage Sand in soil:

$$\% \text{ Sand (w/w)} = \text{Sand weight} \times \frac{100}{\text{Oven-dry soil (g)}}$$

Where: Weight of sand follows from:

Sand weight (g) = [Beaker + Sand (g)] - [Beaker (g)]

Note:

- If possible, all hydrometer jars should be placed in a water bath at constant temperature (20°C); in that case, temperature corrections are not needed.
- For temperature correction, use a value of 0.4 for each degree temperature difference from 20°C. Add or subtract this factor if the temperature is more or less than 20°C, respectively.
- All results of mechanical analysis should be expressed on the basis of oven dry soil (24 hours drying at 105°C).
- In the above procedure, carbonates and organic matter are not removed from the soil.
- The Hydrometer method, as described in this section, cannot be applied to soils that contain free gypsum (gypsiferous soils). For gypsiferous soils.

Sum of % silt and clay + % sand should be 100 %. The magnitude of deviation from 100 is an indication for the degree in accuracy.

Soil Texture

Once the percentage of sand, silt, and clay is measured, the soil may be assigned a textural class using the USDA textural triangle. Within the textural triangle are various soil textures which depend on the relative proportions of the soil fractions.

2.3.2. Determine, implement and monitor plant

Plant tissue analysis is determining, in a laboratory, the total elemental content of the whole plant or parts of plants, typically leaves or petioles (leaf stem). In field crops, plant tissue analysis, in

conjunction with a soil test program, can serve as a check on a fertilizer program. Plant tissue analysis can also serve as a troubleshooting tool to diagnose a suspected nutrient deficiency.

Sample Preparation for Analysis:

Plants were washed at first with running tap water to remove dust, then in 0.001 M HCL followed by 2 times in bidistilled water. Samples are air-dried for few hours, and then dried in a ventilated oven at 70 ºC. After dryness samples are ground in a stainless-steel mill and passed through 0.5 mm sieve, then kept in polyethylene cups till analysis.

2.3.2.1 Determine macronutrients

The digestion of the plant samples is carried out by one of the following methods:

Perchloric acid digestion (wet digestion of plant material):

Principle:

Total content of P, K, Fe, Zn, Cu and Mn are determined in plant samples as sulphate using the wet digestion method with acid mixture (nitric: perchloric : sulphuric acid) at the ratio of (8:1:1).

Reagent:

- Nitric acid AR. Conc.
- Perchloric acid AR. 60%.
- Sulphuric acid AR. Conc.

Apparatus:

- 250 ml kjeldahl flask.
- Whatman no. 42 filter paper.
- Electric heater.
- Funnels
- Measuring flask 50 ml.

Procedure:

1. 1.25 g of ground plant material (oven dried 70ºC) are weighed into a 250 ml digestion flask which has been previously washed with acid and distilled water.
2. 25 ml mixture of HNO_3, $HCIO_4$ and H_2SO_4 at the ratio of 8:1:1 is added.

3. The samples are digested on electric heater until dense white fumes appear and finally the solution is clear and is about 5 ml.
4. Let the sample to cool and dilute it with distilled water and quantitatively transfer it into a 50 ml volumetric flask. The volume makes up to mark with distilled water.
5. Filtration is carried out using filter paper Whatman No. 42.
6. The solution is store for P (spectrophotometer or colorimeter) and K (Flame photometer) Fe, Mn, Cu & Zn (atomic absorption spectrometry).

2.3.2.2. Determine total Nitrogen

Principle:

Organic nitrogen is converted to ammonium sulphate by H_2SO_4. Ammonia is liberated from ammonium sulphate by NaOH or KOH. Ammonia is distilled into boric acid and titrated with N/100 HCI using Tashiro's indicator.

Reagents:

1. Digestion mixture

(a) K_2SO_4

(b) $CuSO_4.5H_2O$

(c) Selenium

(a, b & c are mixed with the ratio of 10:1:0.5 respectively)

2. H_2SO_4 conc.
3. NaOH solution (40%)
4. H_3BO_3 solution (4%)
5. 5. 0.01 N HCI.
6. 6. Tashiro's indicator (0.248 gm methylene blue + 0.375 gm methyl red dissolved in 300 ml ethyl alcohol absolute) (Allen, 1953).

Apparatus:

1. Digestion flask (100 ml).
2. Micro-K jeldahl distillation apparatus.
3. Test tube.
4. Conical flask 100 ml.
5. Dispenser 10 ml.

6. Automatic burette 10 ml.

Procedure:

1. About 0.020 g to 0.030 g of finely dired plant powder (dried at 70 ^{o}C) is weighed.
2. Sample is transferred to a microkjeidahl flask with 0.5 g of catalyst (potassium sulphate: copper sulphate and selenium at the ratio of 10: 1: 0.5 respectively).
3. 2 ml of nitrogen free concentrated H_2SO_4 is added and the sample is completely digested until a clear liquid and free from black residue is obtained.
4. The flask is cooled and its contents are diluted with ammonia free distilled H_2O and quantitatively transferred to a Markham distillation apparatus, then 15 ml of 40% NaOH solution is added through the stoppered funnel at the receiving tip of the condenser.
5. A strong current of steam is passed and distillation is carried out for 5 minutes.
6. The liberated ammonia is received in 10 ml of 4% boric acid solution (approximately 50 ml of distillate).
7. Two drops of Tashiro's indicator (0.248 methylene blue and 0.375 g methyl red dissolved in 300 ml ethyl alcohol absolute), is added to the solution in the receiving flask and then titration of the distillate is performed by using N/100 HCI.

Calculation: Total nitrogen is calculated as mg per g of dry matter in the sample by using the following equation:

$$\text{Titration-blank} \times 0.14 \times \frac{1}{weight\ (g)}$$

The figure 0.14 is a factor when N/100 HCI is used for titration as one milliliter of N/100 HCI = 0.14 mg of nitrogen.

2.3.2.3. Determine of total Phosphorous

Phosphorous is determined in the digested solution by one of the following method:

- Vanadate Molybdate Method:

Vanadate molybdate and orthophosphates react to give a yellow complex in acid solutions. The acid concentration must be above 0.2 N and not over 1.6 N, the final concentration of 0.5 N is recommended. Five millilitres of 5 N nitric acid per 50 ml of final volume are sufficient to give

optimum acidity. The colour develops rapidly but is usually read after 10 minutes to assure full strength.

Determination:

The concentration of phosphorus in the digested material is determined by Micro vanadate molybdate-yellow method. This method is sensitive to 1-20 ppm of P. The developed yellow color is stable for 6 hours at least.

Reagents:

(1) Solution

1: 25 g ammonium molybdate in 400 ml H_2O.

Solution 2:

1.25 gm ammonium metavanadate in 300 ml of boiling H_2O then cooled and 250 ml concentrated HNO3 is added, solution is again cooled to room temperature.

Finally, solution 1 is poured into solution 2 and diluted to 1 liter.

(2) Potassium dihydrogen phosphate (500 ppm P): dissolve 2.197 g dried KH_2PO_4 in 1 L distilled water.

A dilute standard solution is prepared for making up a series of standards (0.05 – 8 ppm) for the calibration curve.

Procedures:

1. 5 ml of the digested solution are transferred to a 50 ml volumet flask.
2. 10 ml of the vanadate solution are added and the volume made up to 50 ml with distilled H_2O.
3. After 10 minutes read at wave length 436 nm against blank.
4. Blank: colour reagent filled to 50 ml with distilled water.

Apparatus:

Spectrophotometer.

Calculations:

$$P\ \% = \frac{Reading \times dilution \times factor}{10{,}000}$$

2.3.2.4. Determine total potassium and sodium

Principles:

Potassium and sodium ions can be determined quantitatively when they are atomized from solution, to burner and exited to spectral emission in a flame. Since the intensity of the light emitted by each element depends primarily on the concentration of its atoms in the flame at any given instant, a measurement of the light intensity produced by a given element takes possible the quantitative determination of that element.

Apparatus:

Flame photometer.

Reagents:

Potassium chloride 1000 ppm: 1.9117 g dried KCl are dissolve in distilled water and make up to 1 L with distilled water.

Sodium chloride 1000 ppm: 2, 5422 g dried NaCl are dissolve in distilled water and make up to 1 L with distilled water.

Standard curve solutions:

Prepare the following dilution 5, 10, 40… 80 ppm

Procedure:

1. 5 ml of the digested solution are transfer to 50 ml volumetric flask, complete to the mark with distilled water.
2. Potassium and sodium concentration are determined by use of the flame photometer and the appropriate calibration curve.

Calculation:

$$\text{K or Na \%} = \frac{Reading \times dilution \times factor}{10{,}000}$$

1.3.3. Determine, implement and monitor soil water

2.3.3.1 Testing water for suitability for plant growth

Many factors taken together determine the quality of water for irrigation of plants. The chemical constituents of irrigation water can affect plant growth directly through toxicity or deficiency, or indirectly by altering plant availability of nutrients.

Once the source of water is identified, water to be used for irrigation should be tested by a reputable laboratory to determine the quality of the water to be used for irrigation, to aid in the choice of fertilizers for optimum plant growth, and to minimize the risk of discharging pollutants to surface or ground water.

Prior to new construction, potential irrigation water should be tested. Monthly analysis is recommended for new water sources. Existing greenhouse operations should monitor water quality at least twice a year (summer and winter); more frequent monitoring is needed to alter production practices in response to changes in water quality.

Collecting a Water Sample

When collecting a water sample, run the water at full flow for five minutes before collecting one pint of water in a tightly sealed plastic bottle. For best results, fill a clean 5 gallon bucket with water and submerge the sample bottle, then seal with the cap under water. Do not use metal lids. The bottle should be totally full with no air space remaining.

Testing by Laboratories

Analysis for inorganic elements should include electrical conductivity (soluble salts), pH, alkalinity, nitrate nitrogen, ammonium nitrogen, calcium, magnesium, sodium, potassium, phosphorus, zinc, copper and aluminum. Testing water for pesticides, herbicides or fuel oil is very expensive, particularly if the contaminant is unknown. Analysis for biological or disease organisms is not generally recommended since many plant pathogens are always present in water at some level. A list of commercial greenhouse water testing laboratories is available under “Resources” at the end of the document.

On-Site Water Testing

Electrical conductivity and pH are two characteristics of water quality that can be tested periodically at the growing facility. This helps the grower get an indication of the consistency of the water supply and check the results of treatments to reduce pH or soluble salts. pH meters range from inexpensive pen types to more sophisticated units. It is recommended to purchase one that can be calibrated using calibration solutions. This ensures that the meter is giving correct readings. Electrical conductivity meters are generally more expensive than pH meters. However, they are very useful for testing water quality and media fertilizer levels during crop growth.

Table1. Target range and Acceptable range of nutrients and other components of irrigation water.

	Target Range in ppm (parts per million) except for pH and EC (electrical conductivity)	**[x]Acceptable Range (in ppm except for pH and EC)**
pH	5.5 to 7.0	4 to 10
EC	0.2 to 0.8 mS (milliSiemen)	0 to 1.5 mS (milliSiemen)
Sodium	0 to 20	less 50
Chloride	0 to 20	less 140
Alkalinity[y]	40 to 160	0 to 400
Ammonia N	NA	less 10
Boron	less 0.1	less 0.5
Nitrate N[z]	NA	less 75
Phosphate	NA	less 30
Potassium	NA	less 100
Magnesium	10 to 30	less 50
Calcium	25 to 75	less 150
Sulfate	0 to 40	less 100
Manganese	less 1	less 2
Iron	less 1	less 4
Boron	less 0.1	less 0.5
Copper	less 0.1	less 0.2
Zinc	less 0.5	less 0.3
Fluoride	less 0.1	less 1
Molybdenum	less 0.1	less 1

[x] No expected crop damage under average environmental conditions. Higher rates of macronutrients may lead to undesired plant growth as in the case of plugs. The acceptable limits

for trace elements and fluoride are dependent on medium pH. These levels may be too high for growing medium pH less than 5.8.

[y] Usually depends on the volume of medium and volume of water applied. The medium pH with smaller volumes of media such as with plugs may be stable with 40 to 80 ppm while medium pH in larger pots with higher rates of fertilization may stabilize at 120 to 160 ppm.

[z] NA – Not applicable Note: Levels of NO3 over 10 ppm may indicate a significant level of contamination and health hazard in drinking water.

2.3.3.2 Determine depth of root zone

The zone between the surface and the effective rooting depth is the interval from which plants obtain their supply of water and nutrients. It is the main factor governing which types of crops are suitable, how they grow, the evapotranspiration, and the crop yield. The effective rooting depth is therefore used as input data in models used to estimate the evaporation loss per unit area.

Calculation of the effective rooting depth is based on the moisture distribution in the soil profile at the end of the growing period in markedly dry years at sites with a low water table. The effective rooting depth is taken as the depth at which the difference between the moisture content and the permanent wilting point is the same as that between the in-situ field capacity and the moisture content. The exact determination of a soil-hydrological parameter such as the effective rooting depth requires time-consuming and expensive field measurements at numerous sites.

For determination of the effective rooting depth in the case of areas that are predominantly forest, the procedure recommended by the soil mapping guidelines was followed, i.e. the value for arable land was obtained and then increased by 20 %. The effective rooting depth was only increased when the effective root zone was not bounded by bedrock, groundwater or a Podsol (ortstein) zone enriched in sesquioxides.

2.3.3.3 Determine depth of water table

Water table is the boundary between two zones in the ground: the zone of aeration (located above the water table), and the zone of saturation (found below the water table). When it rains, water seeps down into the ground due to gravity and it percolates through the gaps or openings in

soil and rock. As a result, water then accumulates and fills up the lower portion, which is called the zone of saturation. Variations in precipitation cause the water table level to fluctuate; as more water is added to the saturation zone, the water table moves closer to the ground surface. As water is used or depleted from the saturation zone, the water table moves further from the surface.

The depth to the water table is the vertical distance between the ground surface and the water table. In many places around the world where people rely on groundwater for drinking water, the depth of the water table can be hundreds of feet or meters deep. The water table being at such a deep depth may complicate the process of extracting it. Drilling for ground water in these areas will likely involve an arduous and long process, wherein several wells are extended to the water table depth and pumped up to the surface.

Water table depth determination

The depth to the water table is a useful measure when planning manure applications. If water is near (within 60 cm/2 feet of) the surface, the risk associated with runoff or infiltration into the water table is great. If you have tile lines in your field, this is typically the depth they are at and can therefore transfer ill-applied manure to surface outlets. Always determine water table depth before manure applications, particularly during times of the year (October-May) when water tables are active and near the surface.

The water table depth can be determined by either using natural features or by digging a representative hole with a shovel or an auger. When digging a test hole, make sure that the area and elevation of the hole is representative of the entire field and is not over a tile line. Dig until water starts entering the hole, or to a maximum depth of 120 cm (4 feet). Allow the hole to settle and observe if water fills the hole within 1 hour. The level that water enters and fills the hole is the water table level. Make note of this depth. Multiple holes may be dug for greater accuracy. Fill the hole back in with the same soil immediately after use. If this is not done, the hole can become a direct conduit to groundwater pollution.

The water table depth can be easily determined by digging a representative hole with a shovel or an auger. Make sure that the area and elevation of the hole is representative of the entire field. Dig until water starts entering the hole, or to a maximum depth of 4 feet. Allow the hole to settle, and observe if water fills the hole within 1 hour. The level that water began to enter the hole, or the level to which it fills it, is the water table level. Make note of this depth. Multiple holes may be dug for greater accuracy. Fill the hole back in with the same soil immediately after use. Instead of digging a hole, you may use a nearby ditch or other natural feature that is representative of the water table.

2.3.3.4 Determining depth of available water

To compute for depth of available water, three essential parameters are needed and these parameters are Apparent Specific Gravity of the Soil (s), Depth of the Root Zone of the Plant (d) and Water Content (m).

The formula for calculating depth of available water:

$d_w = s \,.\, d.\, m$ Where: d_w = Depth of Available Water, s = Apparent Specific Gravity of the Soil, d = Depth of the Root Zone of the Plant. m = Water Content

Example: Find the depth of available water when the apparent specific gravity of the soil is 10, the depth of the root zone of the plant is 8 and the water content is 4.

This implies that;

s = Apparent Specific Gravity of the Soil = 10

d = Depth of the Root Zone of the Plant = 8

m = Water Content = 4

$d_w = s \,.\, d \,.\, m$

$d_w = (10) \,.\, (8) \,.\, (4)$

$d_w = 320$ Therefore, the depth of available water is 320.

Calculating for the Apparent Specific Gravity of the Soil when the Depth of Available Water, the Depth of the Root Zone of the Plant and the Water content is given.

$s = {}^{d_w} / {}_{d \,.\, m}$ Where; s = Apparent Specific Gravity of the Soil, d_w = Depth of Available water, d = Depth of the Root Zone of the Plant, m = Water Content

Let's Solve an example;

Find the apparent specific gravity of the soil when the depth of available water is 60, the depth of the root zone of the plant is 10 and the water content is 3.

This implies that;

d_w = Depth of Available water = 60

d = Depth of the Root Zone of the Plant = 10

m = Water Content = 3

$s = {}^{d_w} / {}_{d \cdot m}$

$s = {}^{60} / {}_{10 \cdot 3}$

$s = {}^{60} / {}_{30}$

s = 2

Therefore, the apparent specific gravity of the soil is 2.

Calculating for the Depth of the Root Zone of the Plant when the Depth of Available Water, the Apparent Specific Gravity of the Soil and the Water content is Given.

$d = {}^{d_w} / {}_{s \cdot m}$ Where; d = Depth of the Root Zone of the Plant, d_w = Depth of Available Water s = Apparent Specific Gravity of the Soil, m = Water Content

Let's Solve an example;

Find the depth of the root zone of the plant when the depth of available water is 30, the apparent specific gravity of the soil is 2 and the water content is 5.

This implies that;

d_w = Depth of Available Water = 30

s = Apparent Specific Gravity of the Soil = 2

m = Water Content = 5

$d = {}^{d_w} / {}_{s \cdot m}$

$d = {}^{30} / {}_{2 \cdot 5}$

$d = {}^{30} / {}_{10}$

d = 3 Therefore, the depth of the root zone of the plant is 3.

Calculating for the Water content when the Depth of Available Water, the Depth of the Root Zone of the Plant and the Apparent Specific Gravity of the Soil is Given**.**

$m = {}^{d_w} / {}_{s.d}$ Where; m = Water Content, d_w = Depth of Available Water, s = Apparent Specific Gravity of the Soil, d = Depth of the Root Zone of the Plant

Let's Solve an example;

Find the water content when the depth of available water is 36, the apparent specific gravity of the soil is 4 and the depth of the root zone of the plant is 3.

This implies that;

d_w = Depth of Available Water = 36

s = Apparent Specific Gravity of the Soil = 4

d = Depth of the Root Zone of the Plant = 3

$m = {}^{d_w} / {}_{s.d}$

$m = {}^{36} / {}_{4.3}$

$m = {}^{36} / {}_{12}$

m = 3 therefore, the water content is 3.

2.3.3.5 Determine readily available water

Steps in identifying Readily Available Water

Step 1: Dig a hole

Dig a hole within the root zone of your crop. For perennial crops: dig under the canopy in an area watered by the irrigation system. Try to dig to 1 meter or at least 30cm past the main root zone (where the fibrous roots are).

Step 2: Identify the effective root zone

The effective root zone is where the main mass of roots is found. This is typically one to two-thirds of the depth of the deepest roots. Some crops, such as irrigated pasture, citrus, bananas, avocados and low-chill stone fruit, develop a mass of shallow roots with only a few roots penetrating deeper into the soil.

Step 3: Identify different soil layers

If you have different soil layers within the effective root zone measure the depth of each of these in meters.

Step 4: Identify gravel/stone in each layer

Stone and gravel reduce the amount of water that can be held by a soil. A very stony soil will hold much less water than the same soil without stones.

Grab three good handfuls of soil and using a 2mm sieve remove all stone and gravel (Figure 4). Place the pile of stones and gravel next to the pile of soil and visually estimate the proportions of each (for example, 60% stone and 40% soils).

Step 5: Identify soil texture(s)

Identify the texture of each soil layer within the effective root zone. The amount of water held by a soil and available to a plant varies with texture. For example, a loamy soil can hold more readily available water than sand.

Soil texture can be assessed in the field by the feel of a moist soil sample when worked between your thumb and forefinger

Step 6: Calculate RAW

1. Identify the depth of the effective root zone.
2. Identify the depth of different soil layers within the effective root zone.
3. Determine the soil texture and percentage stone/gravel of each layer.
4. Select the crop water tension group from Table 1 and identify the RAW value for each soil texture layer (mm/m).
5. Reduce the RAW figure(s) by the % stone/gravel in the soil.
6. Multiply the thickness of each soil layer by its adjusted RAW value.
7. Add up the RAW for each soil layer to obtain the total root zone RAW.

Example calculation

A citrus crop growing in a sandy loam soil containing 20% stone, with an effective root depth of 0.3m and a strategy to irrigate at -40kPa would have the following calculations:

Given the RAW for a sandy loam soil at -40kPa = 60mm/m.

As the soil contains 20% stone, reduce the RAW by 20%. To do this, multiply by 0.8.

Adjusted RAW = 60mm/m x 0.8 = 48mm/m.

Hence, for a rooting depth of 0.3m:

Total root zone RAW = 48mm/m x 0.3m = 14.4mm.

2.4. Characteristics and nutritional status of soils and plant species

Cereal crops have a high requirement for nitrogen, which is crucial for their vegetative growth, chlorophyll formation, and overall productivity. Nitrogen is a key component of proteins and plays a vital role in the synthesis of essential amino acids. Cereal crops require sufficient phosphorus for root development, flowering, and grain formation.

Cereal crops rely on adequate potassium levels for proper root development, photosynthesis, and grain filling. Potassium deficiency can lead to reduced yields, lodging, and increased susceptibility to pests and diseases.

Cereal crops vary in their nutrient use efficiency, which refers to the ability to utilize nutrients effectively for growth and yield production. Improving nutrient use efficiency in cereals is essential for sustainable agriculture and reducing nutrient losses to the environment. Efficient nutrient management practices, including balanced fertilization and precision agriculture techniques, can help optimize nutrient use efficiency in cereal crops.

Pulses have the unique ability to form symbiotic relationships with nitrogen-fixing bacteria called rhizobia. These bacteria reside in nodules on the roots of pulse plants and convert atmospheric nitrogen into a form that can be utilized by the plant this process, known as biological nitrogen fixation.

Like other crops, pulses require phosphorus and potassium for their growth and development. P is important for root development, energy transfer, and overall plant metabolism. K is essential for water and nutrient uptake, enzyme activation, and plant health. Adequate levels of phosphorus and potassium are necessary to support optimal pulse crop growth and productivity.
Rhizobium inoculation is the application of rhizobium bacteria to the seed or soil to promote successful nodulation and nitrogen fixation. Rhizobium inoculants contain specific strains of bacteria that are compatible with the pulse crop being grown.

Pulses are often included in crop rotation systems due to their ability to fix nitrogen and improve soil fertility. By incorporating pulses into rotation, farmers can reduce the reliance on synthetic

nitrogen fertilizers for subsequent crops. The nitrogen fixed by pulses enriches the soil, benefiting subsequent crops with improved nutrient availability and reducing the risk of nitrogen leaching and environmental pollution.

Fruits and vegetables are known for their high nutrient density, meaning they provide a substantial amount of essential vitamins, minerals, and phytonutrients while being relatively low in calories. These nutrients are vital for human health and play various roles in supporting proper growth, development, and overall well-being.

Like other plants, fruits and vegetables require macronutrients, N, P, and K, for their growth and development. However, the specific nutrient requirements can vary among different types of fruits and vegetables. N supports leafy growth and overall plant vigor, phosphorus is important for root development and fruit formation, and potassium aids in water and nutrient uptake, as well as fruit quality and ripening.

Fruits and vegetables are rich sources of various micronutrients, including vitamins (such as vitamin C, vitamin A, and folate), minerals (such as iron, calcium, and magnesium), and antioxidants. These micronutrients are essential for proper functioning of the human body and contribute to overall health and disease prevention.

Oil crops are characterized by their high oil content, which is primarily composed of fatty acids. Fatty acids are essential for energy storage, cell membrane structure, and various physiological processes in plants. The specific composition of fatty acids can vary among different oil crops and affects the nutritional properties of the oil produced. N supports vegetative growth and protein synthesis, P is important for root development and energy transfer, and K aids in water and nutrient uptake and overall plant health. Adequate nutrient availability is necessary to support oil crop productivity and oil accumulation.

Sustainable oil crop production relies on maintaining soil fertility and minimizing nutrient losses to the environment. Proper soil fertility management practices, such as crop rotation, cover cropping, and organic matter addition, help improve nutrient availability and reduce the need for

excessive fertilization. These practices also contribute to soil health, water quality, and overall environmental sustainability.

Root crops, require N for vegetative growth and leaf development. P promotes root development, flowering, and fruit set. K aids in overall plant health, water regulation, and nutrient uptake. Balancing macronutrient availability is crucial for achieving optimal root crop yields and quality. Root crops often accumulate high levels of starch and carbohydrates in their storage roots. These energy reserves play a crucial role in supporting plant growth, reproduction, and storage organs. Some root crops, like potatoes and onions, undergo specific processes called tuberization and bulbing, respectively. These processes involve the formation of enlarged underground structures that store nutrients and energy for subsequent growth and reproduction.

Root crops require adequate moisture for optimal growth. Proper irrigation management is essential to avoid water stress, which can negatively impact root development and yield. Adequate water availability is particularly important during critical growth stages, such as tuberization or bulbing, to ensure sufficient nutrient uptake and storage in the roots.

The timing and method of harvesting root crops can impact their nutritional quality. Proper harvesting techniques, such as avoiding damage to the roots and minimizing exposure to light and air, help preserve the nutritional content. Post-harvest storage conditions also play a role in maintaining the nutritional quality of root crops, as nutrient losses can occur over time.

Bulbous plants require N for supports vegetative growth and leaf development, P promotes root development and flowering, and K aids in overall plant health, water regulation, and nutrient uptake. Proper nutrient management is crucial to ensure optimal bulb formation and quality. Bulbous plants accumulate high levels of carbohydrates, primarily in their bulbs. These carbohydrates serve as an energy source for plant growth and the subsequent development of flowers and seeds.

Bulbous plants are known for their showy flowers and seed production. Optimal plant nutrition, including proper macronutrient and micronutrient availability is crucial for promoting flower bud

initiation, flower development, and seed production. Nutrient deficiencies can result in poor flower quality, reduced seed set, and decreased plant vigor.

Nutritional Status of Plant Species:

It is important to note that the characteristics and nutritional status of soils and plant species can vary significantly across different regions, climates, and agricultural practices. Regular soil testing and plant tissue analysis can provide insights into the specific nutrient requirements and deficiencies of the plant species grown in a particular soil.

Macronutrients: Plant species require macronutrients in relatively large quantities. These include N, P, K, Ca, Mg, and S.

Micronutrients: Plant species also require trace amounts of micronutrients, such as iron (Fe), Mn, Zn, Cu, B, Mo, and Cl.

Different plant species have varying nutrient requirements and abilities to uptake nutrients from the soil. Nutrient deficiencies can lead to visual symptoms like chlorosis (yellowing), stunted growth, or reduced yield.

Nutrient availability and uptake can be influenced by interactions between different nutrients. For example, nutrient imbalances or antagonistic relationships can affect nutrient absorption and plant health.

Plant species may differ in their ability to efficiently utilize nutrients. Some species are more efficient in nutrient uptake and utilization, while others may have higher nutrient demands.

2.5. Integrated soil fertility technologies

Fertilizer use is a key aspect of ISFM. Nutrients must be added to a cropping system to compensate for nutrient removal in the form of harvested produce. ISFM is driven by the efficient use of applied nutrients, which not only maximizes the value of fertilizers, but also minimizes nutrient loss to the environment.

When nutrients are deficient in a system, productivity is limited by the most limiting nutrient, and when multiple nutrients are deficient, all deficiencies must be addressed to achieve optimal nutrient use efficiency.

Three factors have been identified as key to achieving efficient fertilizer use: improved germplasm, organic inputs, and local adaptation.

A. Improved germplasm

Was a key component along with fertilizers, pesticides, and irrigation. Improved germplasm usually means crop varieties breed for disease resistance, high yields, and the ability to use fertilizer efficiently.

B. Organic inputs

Organic matter plays multiple roles in soil health. Soil organic matter increases CEC, water-holding capacity, improves soil structure, increases water infiltration, and hosts soil microbes that are beneficial to soil and plant health. When applied to the soil surface, organic mulches reduce erosion, increase water infiltration, and reduce soil temperature and evaporation losses. Organic inputs can be a challenging aspect of ISFM. The word "input" typically implies an organic source that is brought into the field from an external source, such as compost or farmyard manure. The term "organic resources" is a better fit for the ISFM definition. Organic resources include crop residues, whether grown in rotations, intercrops and relay crops, with legumes that fix biological nitrogen particularly valuable in the ISFM context.

C. Local adaptation

Primary cropping system, livestock intensity, prevailing climate and climate uncertainty, access to irrigation, and market access to inputs and outputs all play key roles in the implementation of ISFM.

ISFM is a set of principles, not a specific cropping system. ISFM principles are designed to intensify production, and as such, access to both input markets (seeds, fertilizers, and crop protection products) and output markets (to sell products and generate income to invest in crop production) are necessary conditions for ISFM adoption.

Implementing crop rotation involves growing different crops in a sequence on the same piece of land. Rotating crops helps break pest and disease cycles, improves soil nutrient availability, and reduces nutrient imbalances. Legume crops in the rotation can also fix atmospheric nitrogen, enriching the soil with this essential nutrient.

Conservation agriculture practices, including minimum soil disturbance, crop residue retention, and cover cropping, play a vital role in ISFM. These practices help improve soil structure, reduce erosion, enhance water infiltration and retention, and promote nutrient cycling.

Using microbial inoculants, such as mycorrhizal fungi and rhizobia, can enhance nutrient uptake by plants. These beneficial microorganisms form symbiotic relationships with plant roots, improving nutrient acquisition, nutrient use efficiency, and overall soil health.

Self-check 2	Written test

Directions: Answer all the questions listed below.

Part I. Write true for the correct statement and false for incorrect statement.

1. Variable rate technology allows farmers to adjust fertilizer application rates based on the specific nutrient needs of different zones within a field.
2. Soil respiration testing measures the release of carbon dioxide from soil microorganisms and is an indicator of overall soil health and biological activity.
3. Cation exchange capacity analysis provides information about the soil's ability to hold and exchange essential nutrients, aiding in the development of tailored fertility management strategies.

Part II. Choose the correct answer from the following alternatives

1. Which soil health assessment method is most appropriate for evaluating microbial activity and overall soil biological diversity?
    a) Soil respiration testing
    b) Cation exchange capacity analysis
    c) Nutrient content analysis
    d) Soil texture determination
2. What technology is commonly used for precision nutrient application to ensure optimal nutrient levels in specific zones of a field?
    a) Variable rate technology (VRT)
    b) Handheld soil pH meters
    c) Soil moisture sensors
    d) Nutrient content analysis
3. In areas prone to salinity issues, which technology would be most effective for monitoring and managing soil salinity levels over time?
    a) Electromagnetic induction (EMI) soil mapping
    b) Drainage ditches and subsurface drainage systems
    c) Green manure cover crops
    d) Soil texture analysis

4. Which technology is commonly employed for assessing soil compaction and determining appropriate management practices to alleviate compaction issues?
    a) Penetrometer measurements
    b) Soil moisture sensors
    c) Electrical conductivity mapping
    d) Soil respiration testing

Part III: Short Answer Questions

1. Why is it important to determine relevant soil health and fertility management technologies for crop production?
2. What factors should be considered when selecting appropriate soil health and fertility management technologies?
3. How can farmers assess the nutrient requirements of their crops to inform their choice of management technologies?
4. What are some common soil health and fertility management technologies that can improve crop production?
5. What role does the use of soil amendments, such as lime or gypsum, play in soil health and fertility management?

Operation Sheet -2 Implementing an Effective Plant Nutrition Program

Objective: To optimize plant nutrition by implementing a comprehensive and effective plant nutrition program for crop production.

Equipment and Materials:

- Soil sampling equipment (e.g., soil auger, soil corer)
- Plant tissue sampling tools (e.g., scissors, plastic bags)
- Laboratory services for soil and plant tissue analysis
- Fertilizers and soil amendments
- Fertilizer spreaders or applicators
- Irrigation system
- Record-keeping sheets or notebooks
- Personal protective equipment (PPE)

Procedures:

Step 1 Soil testing

- Begin by conducting a comprehensive soil test to assess the current nutrient status of the soil.
- Collect soil samples from various locations within the field, ensuring representation of the entire area.
- Analyze the soil samples for essential nutrients such as nitrogen, phosphorus, potassium, and micronutrients.

Step 2 Interpretation of soil test results

- Interpret the soil test results to understand nutrient deficiencies or excesses.
- Pay attention to soil pH, as it can influence nutrient availability. Adjust pH if necessary.

Step 3 Crop nutrient requirements

- Determine the specific nutrient requirements of the target crops at different growth stages.
- Refer to crop nutrient uptake charts and recommendations from agricultural extension services.

Step 4 Fertilizer selection

- Choose fertilizers based on the nutrient requirements identified in the soil test and crop nutrient uptake analysis.
- Consider both organic and inorganic fertilizers, aiming for a balanced nutrient application.

Step 5 Application methods

- Select appropriate application methods such as broadcasting, side dressing, or fertigation.
- Consider the timing of nutrient application in relation to the crop growth stages.

Step 6 Fertilizer rate and timing

- Calculate the precise fertilizer rates required based on crop nutrient needs and soil test results.
- Implement split applications when needed, aligning with the crop's growth stages.

Step 7 Use of technology

- Embrace technology, such as precision agriculture tools, to tailor nutrient applications to specific areas of the field based on variability in soil fertility.

Step 8 Organic matter and cover crops

- Incorporate organic matter into the soil through the use of cover crops and organic amendments.
- Enhance soil structure and microbial activity, promoting nutrient availability.

Step 9 Monitoring and adjustment

- Regularly monitor crop health and growth throughout the season.
- Adjust the nutrient program based on visual observations, plant tissue analysis, and any additional soil tests conducted during the growing season.

Step 10 Record keeping

https://www.youtube.com/watch?v=-HoPDfdllmA

LAP test -2

Name……. ID……..

Date…….

Time started: _____ Time finished: _____

Instructions: Given necessary templates, tools and materials you are required to perform the following task within **1** hour. The project is expected from each student to do it.

Task 1: You are required to implement an effective plant nutrition program

LG #3	LO #3: Determine the requirements for soil health and fertility improvement for crop production

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics:

- Principles of integrated soil fertility management
- Understanding soil fertility and productivity concepts
- Application of improved agronomic practices
- Calculating Agronomic efficiency
- Effects of nutrient deficiency and toxicity
- Cost effective approach of soil amendment practices
- Environmental implications program of ISFM
- OHS hazards and risks
- Coasting resources, tools, equipment and machinery

This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Identify principles of integrated soil fertility management
- Understand soil fertility and productivity concepts
- Apply improved agronomic practices
- Calculate Agronomic efficiency
- Identify Effects of nutrient deficiency and toxicity
- Identify Cost effective approach of soil amendment practices
- Identify Environmental implications program of ISFM
- Identify OHS hazards and risks
- Identify Coasting resources, tools, equipment and machinery

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below.
3. Read the information written in the information Sheets
4. Accomplish the Self-checks
5. Perform Operation Sheets
6. Do the “LAP test”

Information Sheet 3

3.1. Principles of integrated soil fertility management

Integrated soil fertility management aims at the optimal and sustainable use of soil nutrient reserves, mineral fertilizers and organic amendments as well as improved germplasm. Combining increases crop yield and rebuild depleted soils and protect the natural resource base and focuses on application of locally adapted SFM practices.

- Focus on mineral fertilizer Adding nutrients
- Focus on organic resources
- When insufficient nutrients are added to maintain soil fertility: downward spiral into a poverty trap Nutrients from outside the farm are needed! Need to integrate fertilizer and organic resources!
- Integrated Soil Fertility Management 'A set of soil fertility management practices that necessarily include the use of fertilizer, organic inputs and improved germplasm combined with the knowledge on how to adapt these practices to local conditions, aiming at optimizing agronomic use efficiency of the applied nutrients and improving crop productivity. All inputs need to be managed following sound agronomic and economic principles.' Yield = G (genotype) x E (environment) x M (management)
- Principles of production ecology Yield = G (genotype) x E (environment) x M (management) Defining factors YP = G x E YW = G x E x M (water) YA = G x E x M (water) x M (nutrients, pesticides, weeding, etc) Limiting factors Reducing factors.
- Components of ISFM Yield = G (genotype) x E (environment) x M (management) Seeds should be adapted in terms of
  - ✓ Responsiveness to nutrients (M)
  - ✓ Adaptation to the local environment (E)
  - ✓ Resistance to pests and diseases (E).
- Components of ISFM Yield = G (genotype) x E (environment) x M (management)

Source of nutrients, including nutrients not contained in mineral fertilizers. Replenish soil organic matter. Increase the crop response to mineral fertilizer. Improve availability of

phosphorus for plant uptake Regulate soil chemical and physical properties. Create a better rooting environment due to the improvement of the soil structure. Improve the soil's capacity to store moisture Maintain the biodiversity in the soil

- ✓ Supplement recycled or added nutrients from organic sources
- ✓ Contain essential nutrients in a form readily available for plant uptake.

- Positive interaction: fertilizer – organic matter with organic matter without organic matter.
- Local adaptation: Variability between fields Soil fertility gradients within farms:
  - ✓ Fertile home fields
  - ✓ Degraded outfields
- Responsive: (in-field) Less-responsive (outfield, couch grass infestation)

  Low or no response:
  - ✓ Fertile in-fields, due to high amounts of nutrients applied in the past
  - ✓ Degraded soils
  - ✓ Weed infested fields Unresponsive (degraded soil) Unresponsive (degraded soil)
- Increasing Agronomic efficiency (AE): To increase AE (and yield) at a particular fertilizer application rate:
  - ✓ Plant the crop at the right planting density
  - ✓ Apply fertilizer at the right time
  - ✓ Apply fertilizer in the right place
  - ✓ Apply fertilizer in several split applications
  - ✓ Appropriate varieties
  - ✓ Apply appropriate agronomic practices

1.2. Understanding soil fertility and productivity concepts

Soil fertility**:** is the ability of soil to sustain plant growth and optimize crop yield through supplying the nutrients essential for plant growth. Fertility can be enhanced by adding organic and inorganic fertilizers to the soil. It is also defined as "the quality that enables a soil to provide the proper compounds, in the proper amounts, and in the proper balance, for the growth of

specified plants when temperature and other factors are favorable". Fertile soil will contain a pH between 6 and 7.

Factors Governing Soil Fertility

Some factors are involved in soil fertility. These are as follows:

- Parent material: The fertility of soil depends on the chemical composition of the parent material from which it is derived.
- Topography: Soils on the upper slope are less fertile than the soils on a lower slope because of high leaching and erosion on the upper slope.
- Climate: In tropical climates decomposition of organic matter is faster than in temperate climates. Thus soils of tropical regions are less fertile when compared to the temperate regions.
- Depth of Soil Profile: Deep soils are more fertile than shallow soils and the roots are spread well enough in deep soils than the shallow soils.
- Physical Condition of Soil: The soil texture and soil structure influence soil fertility.
- Artificial Factors: Water logging, cropping system, toxic chemicals and pesticides in the soil

A fertile soil possesses following properties:

- The ability to supply essential plant nutrients and moisture for plant growth and development; and
- The absence of toxic substances which may inhibit plant growth.

Soil fertility is mostly related to the factors like**:**

- Sufficient soil depth for optimum root growth
- Good internal drainage for sufficient aeration,
- Sufficient organic matter for healthy soil structure and moisture retention,
- Soil pH in the range 5.5 to 7.0 (required for most plants) and
- Essential plant nutrients in available form.

A fertile soil may not be productive, if physical, biological properties of soil and other agricultural management practices are not correct.

Soil productivity**:** includes soil fertility plus the inherent and management related factors affecting plant growth and development. It is the capability of soil to produce specified crop yield under well-defined and specified systems of management of inputs and environmental conditions.

The main factors governing productivity are soil fertility, climate, pests, disease, genetic potentials of the crop and man's management (tillage, planting date, irrigation schedule, etc.). Thus, soil productivity is an expression of all the factors, soil and non-soil, that influence crop yields.

Soil Productivity is basically an economic concept and not a soil property. Three things are involved:

- Inputs (a specified management system)
- outputs (yield of particular crops), and
- Soil type.

Are Soil Fertility and Soil Productivity Same?

Are all the highly fertile soils productive? 'No' because for soil to be productive it must be fertile. But it does not follow, however, that fertile soil is productive. For example, many fertile soils exist in arid regions, but they are not productive due to a lack of irrigation or favorable temperature. So, all highly fertile soils are not productive, but all productive soils are highly fertile.

Difference between Soil Fertility and Soil Productivity

Soil Fertility	Soil Productivity
1. It is an index of available nutrients to plants.	1. It is used to indicate crop yields.
2. Influenced by the physical, chemical, and biological factors of the soil.	2. Depends upon fertility and location.
3. It is the function of available nutrients in the soil.	3. It is the function of soil fertility, management, and climate.
4. All fertile soils are not productive.	4. All productive soils are fertile.
5. It is an inherent property of the soil.	5. It is not the inherent property of the soil.

3.2. Application of improved agronomic practices

Agronomic practices are the techniques, strategies, and practices used in the cultivation of crops. These include methods of planting, fertilization, pest control, irrigation, and harvest. This practice helps reduce the use of fertilizers and pesticides by delivering them only where they are needed. Soil analysis is used to determine the nutrient content and pH of the soil.

Crop rotation is another common practice that helps to maintain healthy soil by planting different crops in sequential years to avoid soil depletion. Proper irrigation systems are essential for maximizing crop yields, particularly in arid and semi-arid regions. Drought-tolerant crops and more efficient irrigation methods like drip irrigation have become increasingly popular in recent years.

Cropping pattern refers to the proportion of land under cultivation of different crops at different points of time. This indicates the time and arrangement of crops in a particular land area. Any

change in the cropping pattern would cause: change in the proportion of land under different crops and change in space sequence and time of crops.

The major cropping patterns include the following:
Mono-cropping: reduces soil fertility and destroys the structure of the soil. Chemical fertilizers are required to upgrade production. This practice allows the spread of pests and diseases.

Mixed Cropping: When two or more crops are grown on the same land simultaneously, it is known as mixed cropping. This practice minimizes the risk of failure of one of the crops and insures against crop failure due to abnormal weather conditions. The crops to be grown together should have a different maturation time and different water requirements. One tall and one dwarf crop should be grown together. The nutrients required by one crop should be less than those required by the other. One crop should have deep roots, others should be shallow. All these criteria lead to a successful mixed cropping pattern.

Advantages of Mixed Cropping

- The crop yield increases.
- The pest infestation is minimized.
- Reduction in the risk of crop failure.
- The soil is utilized properly.
- More than one variety of crops can be harvested at the same time.

Intercropping: is the practice of growing more than one crop on the same field at the same time in a definite row pattern. After one row of the main crop, three rows of intercrops can be grown. This increases productivity per unit area. Intercropping can be of different types: Row Intercropping: When the component crops are arranged in alternate rows it is known as row intercropping. Strip Intercropping: When two or more crops are grown in wide strips so that the two crops can be managed separately, it is known as strip cropping.

Relay Intercropping: In this type of intercropping, a second crop is planted when the existed crop has flowered but not harvested. For example Rice – Cauliflower – Onion - Summer gourds.

Advantages of Intercropping

- The fertility of the soil is maintained.
- The spread of diseases and pests is controlled.
- Optimum utilization of resources.
- The space and time of growing more than one crop are saved.
- Maximum utilization of nutrients present in the soil.

Maize and soybean are some of the crops grown as intercrops.

Crop Rotation: different crops are grown on the same land in preplanned succession. The crops are classified as one-year rotation, two-year rotation, and three-year rotation, depending upon their duration. Legumes are included in the crop rotation programme to increase soil fertility. The crops which require high fertility level (wheat) can be grown after the legumes.

How are the crops selected for Rotation?

While selecting the crops for rotation, the following criteria should be adopted:

- Enough moisture should be available.
- Availability of fertilizers, man-power, and machine-power.
- Marketing and processing facilities.
- Availability of nutrients in the soil.
- The crop duration- short or long.

Advantages of Crop Rotation

- The soil fertility is maintained for a prolonged period.
- The growth of weeds and pests is prevented.
- A lot of chemical fertilizers are not required.
- The physical and chemical nature of the soil remains unaltered.

Factors Affecting Cropping Patterns

The cropping patterns determine the level of agricultural production. This reflects the agricultural economy of any region. The cropping patterns are affected by changes in agrarian policy, availability of agricultural inputs and improvement in technology. Thus, the cropping patterns are beneficial in improving the fertility of the soil, thereby, increasing the yield of the crops. It ensures crop protection and availability of nutrients to the crops.

Land equivalent ratio (LER): the ratio of the area under sole cropping to the area under intercropping needed to give equal amounts of yield at the same management level. It is also defined as relative land area under monoculture or sole cropping to produce the yield from one hectare in intercropping or polyculture. Its concept is considered for situations where intercropping must be compared with growing each crop sole.

$$LER = \frac{\text{Yield of base crop in intercropping}}{\text{Yield of base crop in sole cropping}} + \frac{\text{Yield of inter crop in intercropping}}{\text{Yield of intercrop in sole cropping}}$$

3.3. Calculating Agronomic efficiency

Agronomic efficiency (AE) is the efficiency of applied nutrients in increasing grain or biomass yield. It is calculated as the increase in yield per unit of nutrient applied. For N application to cereals, typical AE values range from 10 to 30 kg grain kg^{-1} N fertilizer applied.

The AE is the mathematical product of two other Nutrient Use Efficiency (NUE) concepts: recovery efficiency (RE) and physiological efficiency (PE).

The RE is the proportion of the nutrient applied as fertilizer that is taken up by the plant and is influenced by fertilizer management and crop nutrient needs. The PE describes the ability of plants to transform acquired nutrients into economic yield and is impacted by partitioning, environment, and management.

Nutrient use efficiency (NUE) shows the ability of crops to take up and utilize nutrients for maximum yields. Therefore, the NUE concept involves three major processes in plants: uptake, assimilation, and utilization of nutrients.

The AE of a single nutrient such as N is calculated as:

$$\text{AE of N} = \frac{\text{yield in N fertilized - yield in control}}{\text{kg of fertilizer used}}$$

Agronomic efficiency of applied nutrient (kg yield increase per kg nutrient applied)

$$AE = \frac{Y - Y0}{F} \qquad \text{or} \quad AE = RE \times PE$$

Product of nutrient recovery from mineral or organic fertilizer (RE) and the efficiency with which the plant uses each additional unit of nutrient (PE). AE depends on management practices that affect RE and PE.

$$RE = \frac{U - U0}{F} \qquad PE = \frac{Y - Y0}{U - U0}$$

Where: F = amount of fertilizer (nutrient) applied (kg/ha), Y= crop yield with applied nutrients (kg/ha), Y0= crop yield (kg/ha) in a control treatment with no N, U= total plant nutrient uptake in above biomass at maturity (kg/ha) in a plot that received fertilizer, U0= total nutrient uptake in above ground biomass at maturity (kg/ha) in a plot that received no fertilizer.

3.4. Effects of nutrient deficiency and toxicity

3.5.1. Effects nutrient deficiency

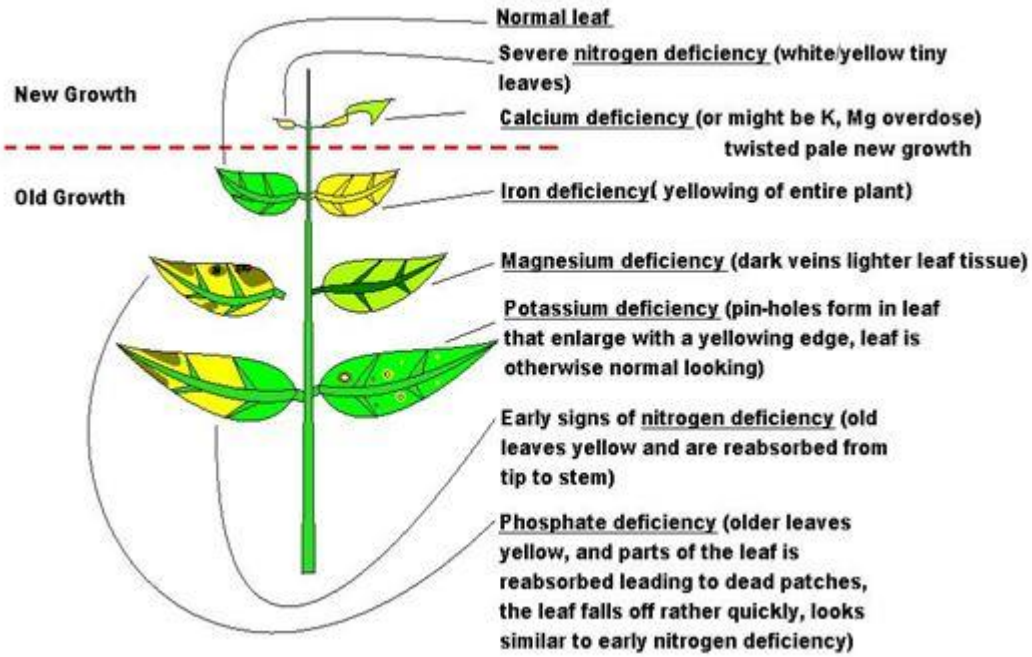
In the absence of any particular element, plants show certain morphological changes. These morphological changes are indicative of certain element deficiencies and are called deficiency symptoms. The parts of the plants that show the deficiency symptoms also depend on the mobility of the element in the plant.

For elements that are actively mobilized within the plants and exported to young developing tissues, the deficiency symptoms tend to appear first in the older tissues. For example, the deficiency symptoms of N, K and Mg are visible first in the senescent leaves. In the older leaves,

biomolecules containing these elements are broken down, making these elements available for mobilize younger leaves.

The deficiency symptoms tend to appear first in the young tissues whenever the elements are relatively immobile and are not transported out of the mature organs, for example, elements like S and Ca are a part of the structural component of the cell and hence are not easily released.

The kind of deficiency symptom shown in plants includes stunted growth, chlorosis, necrosis, premature fall of leaves and buds, inhibition of cell division, reduced yield, poor root development and increased susceptibility to pests and diseases. Chlorosis is the loss of chlorophyll leading to yellowing in leaves. This symptom is caused by the deficiency of elements N, K, Mg, S, Fe, Mn, Zn and Mo. Likewise, necrosis, or death of tissue, particularly leaf tissue, is due to the deficiency of Ca, Mg, Cu, K. Lack or low level of N, K, S, Mo causes an inhibition of cell division. Some elements like N, S, Mo delay flowering if their concentration in plants is low.



Generalized symptoms of plant nutrient deficiency

Nutrients		Visual deficiency symptoms
N	:	Light green to yellow appearance of leaves, especially older leaves, stunted growth, poor fruit development
P	:	Leaves may develop purple colouration, stunted plant growth and delay in plant development
K	:	Marginal burning of leaves, irregular fruit development
Ca	:	Reduced growth or death of growing tips, poor fruit development and appearance
Mg	:	Initial yellowing of older leaves between leaf veins spreading to younger leaves, poor fruit development and production
S	:	Initial yellowing of young leaves spreading to whole plant, similar symptoms to N deficiency but occurs on new growth
Fe	:	Initial distinct yellow or white areas between veins of young leaves leading to spots of dead leaf tissue
Mn	:	Interveinal yellowing or mottling of young leaves
Zn	:	Interveinal yellowing on young leaves, reduce leaf size, short internodes, brown leaf spot on paddy
Cu	:	Stunted growth, terminal leaf buds die, leaf tips become white and leaves are narrowed and twisted.
B	:	Terminal buds die, breakdown of internal tissues in root crops, internal cork of apple, impairment of flowering and fruit development
Mo	:	Resemble N deficiency symptoms, whiptail diseases of qualiflower, leaves show scorching and whithering
Cl	:	Chlorotic leaves, some leaf necrosis

Nutrient deficiency can be correct by (i) addition of nutrient through fertilizer in soil as well as foliar application and (ii) addition of organic manure as per fertilizer recommendation.

3.5.2 Effects nutrient toxicity

The requirement of micronutrients is always in low amounts while their moderate decrease causes the deficiency symptoms and a moderate increase causes toxicity. In other words, there is a narrow range of concentration at which the elements are optimum. Any mineral ion concentration in tissues that reduces the dry weight of tissues by about 10% is considered toxic. Such critical concentrations vary widely among different micronutrients. The toxicity symptoms are difficult to identify. Toxicity levels for any element also vary for different plants. Many a times, excess of an element may inhibit the uptake of another element. Nutrient toxicities in crops are more frequent for Mn and B than for other nutrients.

Manganese toxicity is found on acid soils. It is important to know that manganese competes with Fe and Mg for uptake and with Mg for binding with enzymes. Mn also inhibits calcium translocation in shoot apex. Therefore, excess of Mn may, induce deficiencies of Fe, Mn and Ca. Thus, what appears as symptoms of manganese toxicity may actually be the deficiency symptoms of Fe, Mg and Ca.

Boron toxicities occur in irrigated regions where the well or irrigation waters are exceptionally high in B. Most other nutrient toxicities occur when large amounts of nutrients in question have been added in waste, e.g., sewage sludge. Crops grown near mines and smelters are prone to nutrient toxicities. Generally, the symptoms of toxicity in crops occur as burning, chlorosis or browning, altered physiology, growth inhibition, reduced flowering and fruit set and yellowing of leaves. Toxicities can result in decreased yield and/or impaired crop quality.

Prevention of toxicity

- With the exception of Mo, toxicity of other nutrients can be reduced by liming.
- Following recommended rates of fertilizers and the safe and controlled use of waste materials, such as sewage sludge and coal fly ash should reduce metal loading and nutrient toxicity in crops.
- Use of crop species and genotypes less susceptible to toxicity are recommended where toxicity is suspected.

- Provided sufficient drainage because availability of nutrients like Fe and Mn is increases up to toxicity level under water logged condition.
- Ground water must be monitored regularly, if content of B and Cl is too high stop to applied water or applied with dilution.
- Addition of sufficient amount of organic matter binds some of the toxic elements.
- Ploughing in dry soil so increase the infiltration rate and leach the toxic element with rain water.

3.5. Cost effective approach of soil amendment practices

Soil amendments are products added to soils to improve soil qualities like soil fertility. Many of the soil amendments that can improve soil health also sequester carbon. Amendments that increase soil organic matter may improve the water holding capacity and infiltration in soils, which promotes resilience to climate-related impacts such as drought, heat waves, or heavy rains. Additionally, amendments can promote biological activity and supply vital nutrients, resulting in healthier plants that are less vulnerable to pests and disease.

Soil amendments are generally used to improve conditions for plant growth; these include organic matter such as biochar, mineral and organic fertilizers, and inoculum of mycorrhizae or other microbes. The efficacy of microbial inoculations has been limited, and the microbial community in the inoculum is usually overwhelmed by the microbes already endemic to a particular site.

A. Organic matter:

Organic matter in soil ranges from fresh unchanged organic materials to highly decomposed organic materials. So the organic matter consists of soil biota (living organisms and roots), plant fragments, and polysaccharides, proteins, fats, lignin, waxes, resin, humus, and charcoal.

Organic matter contains carbon. Carbon is a source of energy for microorganisms (microbes) in the soil. These are microscopic plants and animals such as bacteria, fungi, and actinomycetes. Organic matter provides food for a diverse population of microbes in the soil and this helps prevent any one type of organism such as a plant pathogen from dominating.

Improves moisture holding capacity of sandy soils, aeration of clay soils and how it helps over-all tilth of any soil. SOM is the chief contributor to cation exchange capacity, a measure of a soil's ability to retain nutrients.

Soil microbes are also influenced by soil pH. This is especially true of bacteria. Under acid conditions, bacterial activity in breaking down organic matter is greatly reduced. Soil fungi responsible for breakdown of SOM are generally less affected by low pH. In most cases, however, bacteria are responsible for most of the decomposition of SOM, and as a rule this process is process is markedly slowed if pH levels drop below 6.0.

Soil temperature has a marked influence on microbial activity. The optimum soil temperatures for bacterial activity are in the 70^{o} F to 100^{o} F range, but activity occurs as low as 40^{o} F, although at greatly reduced rates.

The resistant materials remain and form the dark colored material called humus. Humus continues to decompose, but at a very slow rate. Carbon dating has shown some humus to be thousands of years old. Humus forms the colloids which contribute to increased cation exchange capacity and good soil structure.

Carbon to Nitrogen ratio

Since organic matter is broken down by microbes which use carbon for energy. They also have a high requirement for nitrogen. Microbes have a requirement of about one nitrogen atom for each 25 carbon atoms. This is a carbon-to-nitrogen ratio (C:N) of 25:1 or 25. If the organic matter has a higher C: N, microbes will need more nitrogen than is in the organic matter and will take it from the soil. Microbes are more efficient than crops in obtaining nitrogen from the soil. If there is not enough nitrogen for both the microbes and the crop, the crop will not obtain what it needs. Eventually there will be a net gain in nitrogen, but crops can suffer in the short term. If organic matter with a high C:N is applied to soil shortly before planting a crop, additional nitrogen may be needed to assure that the needs of both the microbe and the crop are met. See Table 1 for examples of C: N's of some sources of organic matter.

MATERIAL	C:N RATIO
Legume hay	15-19:1
Non-legume hay	24-41:1
Corn stalks	42:1
Oat straw	70:1
Rye straw	82:1
Cow manure	8:1
Finished compost	17-20:1
Agricultural soils	8-14:1
Hardwood sawdust	500:1

Table 3.1: Typical carbon to nitrogen ratios

Organic matter in soil affects the growth and production of fruit trees chemically, biologically, and physically in the following ways:

- Directly and indirectly provides nutrients to the trees and cover crops
- Provides nutrients and energy for the many organisms (microorganisms and animals) in soil
- Helps to buffer soil against big swings in pH when chemicals are added to soil
- Improves structure and resilience of soil, and so affects the supply of water and air to roots and microorganisms
- Organic residues act as slow-release fertilizers. The nutrients attached to the humus are not easily leached down to the groundwater away from the roots. However, the orchardist still needs to add inorganic fertilizer to make up for nutrients removed at harvest.

The amount of organic matter in soil depends on:

- amount and quality of the organic residues returned to soil
- soil texture, depth, and density
- soil pH
- temperature, water content, and aeration of soil
- microbial population

Sometimes a soil test shows organic matter as organic carbon. To calculate the percentage of organic matter, multiply the percentage of organic carbon by 1.6.

Organic residues of high quality, i.e., with a low ratio of carbon to nitrogen (less than 18:1), are decomposed quickly as there is enough nitrogen to stimulate microbial activity; organic residues with a high carbon-to-nitrogen ratio of more than 60:1 are decomposed very slowly. Simple sugars, simple proteins, and starch are easily decomposed, whereas hemicellulose, cellulose, fats, waxes, and resins are slowly decomposed.

Nutrients with positive charges, such as potassium, calcium, and magnesium, adhere to the negative charges on the humus, whereas nutrients with negative charges, such as phosphate and sulphate, adhere to positive charges. In both cases, the nutrients remain available to plants and are not leached down beyond the root zone. A soil's CEC is a measure of the net negative charge of dry soil and, therefore, is a measure of the amount of positive nutrients that can be stored. Soils with a low CEC have a low net negative charge and do not hold positive nutrients in the soil as well as do soils with a high CEC. Organic matter, with its negative charge, can help improve soils with low CEC.

B. Cover Crops:

It is also known as green manure or living, are crops grown primarly to benefit the soil and ecosystem rather than for harvest. They are typically planted between cash crops or during follow periods to protect and improve the soil.

C. Raw Manure:

It is a valuable organic fertilizer that has been used in agriculture for centuries. Here's a short note on raw manure or animal manure:

- Raw manure is rich in essential plant nutrients, including N, P, and K, as well as micronutrients. The nutrient content varies depending on the animal species, diet, and management practices. For example, poultry manure tends to be higher in nitrogen, while ruminant manure (e.g., cow or sheep) has a more balanced nutrient profile. However, the nutrient content in raw manure is typically higher than that of synthetic fertilizers.
- Raw manure contains organic matter, which enhances soil structure, water-holding capacity, and nutrient retention. It helps improve soil fertility and promotes beneficial microbial activity in the soil. .

D. Compost:

Soil amendment by compost involves the incorporation of composted organic matter into the soil to improve its physical, chemical and biological properties. Compost is a nutrient-rich material created through the decomposition of organic waste, such as food scraps, yard trimmings or agricultural residue.

Organic vs. Inorganic Amendments: There are two broad categories of soil amendments: organic and inorganic. Organic amendments come from something that was alive. Inorganic amendments, on the other hand, are either mined or man-made. Organic amendments include sphagnum peat, wood chips, grass clippings, straw, compost, manure, biosolids, sawdust and wood ash. Inorganic amendments include vermiculite, perlite, tire chunks, pea gravel and sand.
Organic amendments increase soil organic matter content and offer many benefits. Over time, organic matter improves soil aeration, water infiltration, and both water- and nutrient-holding capacity.

Factors to consider when choosing an amendment
There are at least four factors to consider in selecting a soil amendment:

- how long the amendment will last in the soil,
- soil texture,
- soil salinity and plant sensitivities to salts, and
- Salt content and pH of the amendment.

3.6. Environmental implications program of ISFM

When managed sustainably, soils can play an important role in climate change mitigation by storing carbon (carbon sequestration) and decreasing greenhouse gas emissions in the atmosphere. Conversely, if soils are managed poorly or cultivated through unsustainable agricultural practices, soil carbon can be released into the atmosphere in the form of CO_2, which can contribute to climate change. The steady conversion of grassland and forestland to cropland and grazing lands over the past several centuries has resulted in historic losses of soil carbon worldwide. However, by restoring degraded soils and adopting soil conservation practices, there is major potential to decrease the emission of greenhouse gases from agriculture, enhance carbon sequestration and build resilience to climate change.

A substantial amount of global CO_2 comes from soil through decomposition, mineralization and soil respiration. So when fertilizers were added to the soil through integrated way the decomposition rate was reduced and carbon dioxide emission was altered.

Nutrient management strives to balance the withdrawal of soil nutrients from fields, pastures and orchards by crops, livestock and natural processes with the addition of nutrients provided by crop residues, compost, manure or commercial fertilizers. Failure to properly manage nutrients results in poor nutrient use efficiency and potentially harmful downstream environmental effects. Good nutrient management prevents the over-application of essential crop nutrients and sustainable nutrient management considers the full cost associated with application, including the energy embedded in added nutrients.

Climate change mitigation involves reducing the amount of greenhouse gases in the atmosphere or enhancing their sinks, e.g., by reducing the use of fossil fuels, planting trees, or enhancing mineralization of organic matter into soil organic carbon. Adopting the INM strategy is essential to SOC sequestration. The sink capacity of SOM for atmospheric $C0_2$ can is greatly enhanced when soils are treated with integrated nutrient management instead of treating it with organic or inorganic source of nutrient.

3.7. OHS hazards and risks

While Integrated Soil Fertility Management (ISFM) practices offer numerous benefits, it is important to be aware of and address potential occupational health and safety (OHS) hazards and risks associated with their implementation.

i. Chemical Hazards:

The use of chemical fertilizers, pesticides, or soil amendments may expose workers to hazardous substances. These substances can include toxic chemicals, irritants, or allergens that pose risks of inhalation, skin contact, or ingestion. Workers should follow proper handling, storage, and application procedures, including wearing appropriate PPE and ensuring adequate ventilation.

ii. Manual Handling and Ergonomic Hazards:

Soil management activities, such as digging, lifting heavy bags or equipment, and repetitive movements, can lead to musculoskeletal injuries. Workers may experience strains, sprains, or

overexertion if they do not use proper lifting techniques or if they perform repetitive tasks without adequate rest breaks.

iii. Machinery and Equipment Hazards:

The use of machinery and equipment, such as tractors, tillers, or spreaders, can pose risks if not operated or maintained properly. Workers may face hazards such as entanglement, crushing, or being struck by moving parts.

iv. Slips, Trips, and Falls:

Working in outdoor environments with uneven terrain, slippery surfaces, or debris increases the risk of slips, trips, and falls. Wet soil, mud, or uneven ground can lead to accidents and injuries. Workers should wear appropriate footwear with good traction, maintain clear walking paths, and use caution when working on unstable surfaces.

v. Heat and Sun Exposure:

Exposure to high temperatures can cause heat exhaustion or heat stroke, while prolonged exposure to the sun without protection can lead to sunburn, skin cancer, or heat-related illnesses. Employers should provide shaded areas, access to drinking water, and encourage the use of sun protection measures such as hats, sunscreen, and appropriate clothing.

vi. Biological Hazards:

Working with organic materials, such as compost or manure, may present biological hazards. Exposure to pathogens, bacteria, or allergens from organic waste can lead to infections, respiratory issues, or allergic reactions. Workers should use appropriate PPE, such as gloves and masks, practice good hygiene, and follow proper waste management procedures to minimize exposure risks.

vii. Environmental Hazards:

Outdoor work exposes workers to various environmental hazards, including extreme weather conditions, such as storms, lightning, or cold temperatures.

3.8. Coast resources, tools, equipment and machinery

It is important to select and use resources, tools, equipment, and machinery that are appropriate for the scale of operations and specific soil fertility management practices being implemented.

1.8.1. Resources

- Organic matter: This includes compost, manure, crop residues, cover crops, or green manure, which are essential for improving soil fertility and organic content.
- Water: Adequate water resources are necessary for irrigation and maintaining soil moisture levels.
- Arial photograph, charts and tables of soil

1.8.2. Tools

- Shovels: Used for digging, turning soil, and incorporating amendments.
- Rakes: Useful for leveling soil, removing debris, or spreading compost.
- Hoes: Ideal for weeding, cultivating, or creating furrows.
- Hand trowels: Handy for transplanting seedlings or small-scale planting.
- Pruning shears: Used for trimming plants or removing unwanted branches.
- Wheelbarrows or garden carts: Assist in transporting materials, compost, or harvested produce.
- Soil testing kits: Essential for assessing soil nutrient levels, pH, and other properties.

1.8.2.1. Charts and illustrations of symptoms of plant nutrient deficiencies

It is visual tools used to identify and diagnose nutrient imbalances in plants. They typically feature images or diagrams depicting the characteristic symptoms exhibited by plants lacking specific essential nutrients.

By comparing the visual symptoms displayed in the charts to the observed symptoms in their own plants, individuals can make informed decisions about appropriate remedial actions.
Common symptoms depicted in these visual aids include leaf discoloration, yellowing or browning of leaves, stunted growth, leaf spot formation, interveinal chlorosis (yellowing between leaf veins), leaf curling, and wilting, among others.

These tools are essential for diagnosing nutrient deficiencies early, as prompt identification allows for timely corrective measures. By addressing nutrient imbalances, growers can optimize plant growth, yield, and overall health.

Charts and illustrations of symptoms of plant nutrient deficiencies are widely available in various formats, including books, posters, online resources, and mobile applications. They provide a practical and visual reference for growers and gardeners, assisting them in maintaining optimal nutrient levels and promoting healthy plant development.

https://www.pinterest.com/pin/6262886975153864/

1.8.2.1 Hand-held salinity or electrical conductivity meters

Hand-held salinity or electrical conductivity meters are compact, handheld tools designed for quick and convenient on-site measurements. They consist of a probe or sensor that is immersed in the liquid being tested and a display unit that provides readings of the conductivity or salinity levels.

These meters operate on the principle that the conductivity of a solution is directly related to the concentration of ions or dissolved salts present in the solution. When the probe is placed in the liquid, it measures the electrical conductivity, which is then correlated to the salinity levels or the concentration of dissolved constituents.

The key features and functionalities of hand-held salinity or electrical conductivity meters include:

- Measurement Range: These meters often have a wide measurement range, allowing them to measure a broad spectrum of conductivity or salinity levels. The range can be adjusted depending on the application and the expected conductivity values of the samples.
- Calibration: Hand-held meters usually require periodic calibration to ensure accurate measurements. Calibration involves using standard solutions with known conductivity or salinity values to adjust the meter's readings and account for any measurement drift or variations.
- Temperature Compensation: Many hand-held meters incorporate temperature compensation features to account for temperature variations, as conductivity is influenced by temperature changes. This compensation ensures more accurate readings by correcting for temperature effects.

- Display and Readability: These meters typically have a clear, easy-to-read display that shows the conductivity or salinity readings. The display may also provide additional information, such as temperature, calibration status, and measurement units.
- Portable and Battery-Powered: Hand-held salinity or electrical conductivity meters are designed to be portable, allowing for field measurements. They are often battery-powered, enabling operation without the need for external power sources.
- Applications: These meters find applications in various fields, including agriculture, hydroponics, aquaculture, environmental monitoring, water quality analysis, and research. They are used to assess soil salinity, measure water quality parameters, monitor nutrient levels in hydroponic systems, and evaluate the suitability of water for specific purposes.

1.8.2.2. pH test kit or electronic pH testing device

Electronic pH testing devices, also known as pH meters or pH testers, are portable electronic devices specifically designed to measure the pH level of a solution with higher accuracy and precision. They typically consist of a probe or electrode that is immersed in the liquid being tested and a digital display unit that provides real-time pH readings.

Electronic pH testing devices operate based on the principle of measuring the voltage generated by the interaction between the sample and the electrode. They often offer additional features such as automatic temperature compensation, data storage, and calibration options.

These devices are widely used in scientific research, water quality analysis, environmental monitoring, food and beverage production, and various industrial applications where accurate pH measurements are crucial.

1.8.3. Protective Gear

- Personal Protective Equipment (PPE): This may include gloves, boots, safety glasses, masks, or respirators, depending on the specific hazards associated with the task.
- Sun protection: Hats, sunscreen, and protective clothing for working in sunny conditions.

- Protective clothing: Durable clothing to protect against potential cuts, abrasions, or exposure to chemicals.

1.8.4. Soil Amendments and Fertilizers

- Organic fertilizers: Composted manure, compost, or other organic-based fertilizers.
- Synthetic fertilizers: Chemical-based fertilizers that provide specific nutrient supplements.
- Lime or sulfur: Used to adjust soil pH, depending on specific crop requirements.

1.8.5. Equipment and Machinery

- Tractors: Used for various tasks like ploughing, tilling, or spreading amendments on larger scales.
- Tillers: Power tillers or cultivators help prepare the soil by breaking it up and incorporating amendments.
- Seeders or planters: Mechanized equipment for efficient seeding or planting of crops and Air Blower Machine
- Irrigation systems: Sprinklers, drip irrigation, or other systems for providing controlled water supply to crops.
- Harvesting equipment: Depending on the scale of cultivation, machinery like combine harvesters or hand tools like sickles may be required.

1.8.5.1. Air blowers

Air blowers are mechanical devices used to generate and direct a stream of air. They are commonly used in various industries and applications for tasks such as ventilation, cooling, drying, and cleaning.

Air blowers are designed to move air or gas from one location to another. They create airflow by using an impeller or a fan blade that rotates at high speed, drawing in air and propelling it forward.

Types of Air Blowers: There are different types of air blowers available, including:

- Centrifugal Blowers: These blowers use centrifugal force to propel air radially outward from the impeller. They are known for generating high-pressure airflow and are commonly used in HVAC systems, industrial processes, and pneumatic conveying.
- Axial Blowers: Axial blowers move air parallel to the impeller's axis, creating a high-volume, low-pressure airflow. They are often used for cooling or ventilation purposes in applications such as air conditioning, cooling towers, or exhaust systems.
- Positive Displacement Blowers: These blowers use rotating lobes or screws to trap and transport air or gas. They are suitable for applications requiring constant airflow and pressure, such as aeration in wastewater treatment, pneumatic conveying, or industrial processes.

Applications:

- Ventilation: Air blowers are used to circulate and exchange air in enclosed spaces, improving air quality and controlling temperature and humidity. They are commonly found in HVAC systems, industrial ventilation, and building ventilation systems.
- Cooling: Air blowers help dissipate heat by providing forced airflow over heat-generating equipment or surfaces. They are used in cooling systems for electronics, machinery, engines, or industrial processes.
- Drying: Air blowers facilitate drying processes by directing a stream of air to remove moisture from surfaces, materials, or products. They are employed in applications such as drying food products, drying carpets or floors, or accelerating paint drying.
- Cleaning: Air blowers are used for blowing away dust, debris, or contaminants from surfaces or equipment. They are often found in cleaning applications in industries like automotive, electronics, or manufacturing.

Factors to Consider:

- Airflow Capacity: The airflow capacity of an air blower determines its performance and suitability for specific applications. It is typically measured in cubic feet per minute (CFM) or liters per second (L/s).

- Pressure: Blowers can generate different levels of pressure, which affects their ability to overcome resistance or deliver air to specific locations. Pressure is measured in units like inches of water gauge (inWG) or pascals (Pa).
- Power Source: Air blowers can be powered by electricity, gasoline engines, or compressed air systems.
- Noise Level: Consideration should be given to the noise produced by the air blower, especially in indoor or residential settings.

1.8.5.2. Backpack spray equipment

Backpack sprayers or knapsack sprayers, are portable tools used for applying liquids, such as pesticides, herbicides, fertilizers, or foliar nutrients, to plants or targeted areas. The pump mechanism, typically operated by hand, builds pressure inside the tank. As the pressure increases, it forces the liquid through a hose and out of a nozzle or spray wand. The nozzle or wand can be adjusted to control the spray pattern, such as a wide fan spray or a concentrated stream.

Backpacks sprayers are commonly used in various applications, including agriculture; horticulture, landscaping, and pest control, and weed management.

They offer several advantages:

- Portability: The backpack design allows the operator to move freely and access hard-to-reach areas, such as dense vegetation or uneven terrain. It is especially useful in areas where larger equipment cannot maneuver.
- Versatility: Backpack sprayers can accommodate different types of liquids, including water-based solutions, emulsifiable concentrates, wettable powders, or suspension fertilizers. This versatility makes them suitable for various tasks, from applying pesticides for pest control to foliar feeding of plants.
- Precise Application: The adjustable nozzles or wands enable precise targeting of the spray, minimizing waste and reducing off-target effects. This precision is particularly important when applying chemicals in sensitive areas or near desirable plants.

- Efficiency: Backpack sprayers provide a convenient and efficient way to apply liquids over a relatively large area. The operator can cover more ground quickly without the need for carrying heavy containers or relying on less efficient manual application methods.

1.8.5.3. Backhoe machinery

Backhoe machinery is a type of excavating equipment that consists of a tractor-like unit with a digging bucket on the rear end and a loader bucket on the front. It is named "backhoe" because the digging bucket is mounted on a hinged arm, allowing it to dig by moving backward towards the machine.

The backhoe attachment is used for digging and excavation tasks, such as trenching, digging foundations, and removing soil. The bucket on the front end of the machine serves as a loader for moving materials, such as sand, gravel, or debris. This dual functionality makes the backhoe a versatile machine capable of performing a wide range of tasks on construction sites, farms, and road maintenance.

1.8.5.3 Irrigation systems set up for fertigation

Fertigation is a method of fertilizer application in which fertilizer is incorporated within the irrigation water by the drip system. In this system fertilizer solution is distributed evenly in irrigation. The availability of nutrients is very high therefore the efficiency is more. By this method, fertilizer use efficiency is increased from 80 to 90 per cent.

Advantages of fertigation

- Nutrients and water are supplied near the active root zone through fertigation which results in greater absorption by the crops.
- As water and fertilizer are supplied evenly to all the crops through fertigation there is possibility for getting 25-50% higher yield.
- Fertilizer use efficiency through fertigation ranges between 80-90 per cent, which helps to save a minimum of 25% of nutrients.
- By this way, along with less amount of water and saving of fertilizer, time, labour and energy use is also reduced substantially.

Fertigation equipments

Three main groups of equipments used in drip system are:

- Ventury: Construction in the main water flow pipe causes a pressure difference (Vaccum) which is sufficient to suck fertilizer solution from an open container into the water flow. It is very easy to handle and it is affordable even by small farmers. This equipment is most suitable for smaller area.
- Fertilizer tank: A tank containing fertilizer solution is connected to the irrigation pipe at the supply point. Part of the irrigation water is diverted through the tank diluting the nutrient solution and returning to the main supply pipe. The concentration of fertilizer in the tank thus becomes gradually reduced.
- Fertilizer pump: The fertilizer pump is a standard component of the control head. The fertilizer solution is held in non-pressurized tank and it can be injected into the irrigation water at any desired ratio. Therefore the fertilizer availability to each plant is maintained properly.

1.8.5.4. Pumps and pump fittings

Pumps and pump fittings are essential components in fluid handling systems, responsible for transferring liquids or gases from one location to another.

Pumps:

Pumps are mechanical devices designed to create flow and generate pressure to move fluids. They can be categorized into various types based on their operating principles, including:

- Centrifugal Pumps: These pumps use a rotating impeller to impart centrifugal force to the fluid, causing it to move radially outward and create pressure.
- Positive Displacement Pumps: Positive displacement pumps trap and move a fixed volume of fluid with each stroke or rotation. They are suitable for applications where a constant flow rate is required, such as in oil and gas industry, chemical processing, or food and beverage production.

- Submersible Pumps: Submersible pumps are designed to operate submerged in the fluid they are pumping. They are commonly used for applications like drainage, sewage pumping, well water extraction, or dewatering in construction.

Pump Fittings:

It is also known as pump accessories or pump components, are the accompanying parts that complement and facilitate the installation, operation, and maintenance of pumps. Some common pump fittings include:

- Pipe and Hose Connections: Pump fittings include adapters, couplings, flanges, and connectors that allow the pump to be connected to pipes or hoses for fluid transfer.
- Valves: Valves control the flow and pressure of fluids in the pumping system. Examples include check valves, gate valves, ball valves, and control valves.
- Gauges: Gauges are used to measure and monitor pressure, temperature, or other parameters in the pump system. They provide important information for maintaining proper operation.
- Strainers and Filters: These fittings remove debris, solids, or impurities from the fluid before it enters the pump, protecting the pump from damage and maintaining its efficiency.

1.8.5.5. Seeding Machine (Seeder, Seed Drill)

The uses of seeders or seeding machines in agriculture sows seeds for crops by dropping seeds into a straight furrow within the soil at precise rates and specific depths. With seeding machines, seeds are distributed in rows; however, the distance between seeds along the row cannot be adjusted due to the nature of working with smaller seeds like cereals and grains.

Seed Drill: is a machine for placing the seeds in a continuous flow in furrows at uniform rate and at controlled depth and covering them with soil.

Function of seed drill

- To carry the seeds
- To open furrow to an uniform depth
- To meter the seeds

- To place the seed in furrows in an acceptable pattern
- To cover the seeds and compact the soil around the seed

Seed cum Fertilizer Drill:

Seed drills, fitted with fertilizer dropping attachment, distribute the fertilizer uniformly on the ground. This machine has a large seed box which is divided length-wise into two compartments, one for seeds and another for fertilizers.

Seedling Planter: is primarily utilized for manual sowing of cartridge seedlings in one row in open ground. Seeding planters assist the transplanting process and expand the potential production of farm. This help in making the transplanting process easier and faster with less manpower. It provides various benefits which include easy process, high efficiency, economical and easy to operate, etc. Seedling planters are utilized for planting of various vegetables like onion, tomato, maize, cucumber, carrot, etc.

Seeder Parts

Though there are several distinct types of grass seeders, most of them have the same general components. Understanding these parts will help you make the best decisions about what planter equipment will work best for your farm.

- Seedbox or hopper – The seedbox or hopper holds the seeds that the seeder will distribute. Seedboxes come in three standard configurations: standard, legume, and native grass or fluffy seed.
- Seed tubes – Seed tubes connect to the box or hopper and deliver the seeds through the ground openers and into the prepared furrow.
- Ground openers – Ground openers or disc openers dig the trenches the seeds go into. On a no-till drill, the ground openers will be strong to cut through untilled vegetation and thick sod.
- Gauge wheels – Gauge wheels set the appropriate depth for the seeds.
- Covering device – Covering devices or closing discs cover the seed with soil as the seeder moves through the field.

Standard Drill Seeders

Standard drill seeders or box drills rely on gravity to function. These common planters usually place seeds in rows between six and eight inches apart.

The seeding equipment can be classified according to the power source.

- Manual drawn equipment
- Bullock drawn equipment
- Power tiller drawn equipment
- Tractor drawn equipment.

How do Fertilizer Spreaders Work?

Here is a general overview of how fertilizer spreaders work:

- Hopper: The hopper is the container that holds the material being spread. It can be made of plastic, steel, or other materials and may have a capacity ranging from a few hundred pounds to several tons.
- Agitator: The agitator is a mechanism inside the hopper that helps to break up clumps and ensure that the material flows smoothly through the spreader.
- Discharge mechanism: The discharge mechanism is what allows the material to exit the hopper and be spread over the field. This can vary depending on the type of spreader, but it typically involves a rotating disc or set of discs, a series of drop tubes, or a pneumatic system.
- Control mechanism: The control mechanism determines the rate at which the material is spread. This can be adjusted manually on some spreaders or controlled electronically on more advanced models.
- Spreading pattern: The spreading pattern is determined by the design of the discharge mechanism and the speed of the spreader. Some spreaders are designed to spread material in a circular pattern, while others spread it in a more precise pattern.

To use a fertilizer spreader, the hopper is filled with the desired material and the spreader is mounted to or towed behind a tractor. The operator adjusts the control mechanism to achieve the desired application rate and spreading pattern and the material is spread over the field as the spreader moves forward.

Advantages of using a Fertilizer Applicator

- The fertilizer applicator ensures that fertilizers are applied to plants in a uniform manner.
- It enhances efficiency in the process of fertilizer application.
- It prevents soil compaction caused by heavy machines used for the application of fertilizer.
- It is easy to operate. Little or no training is needed before a farmer can use the fertilizer application.
- The fertilizer applicator is light in weight and easy to carry.
- It can reduce the cost of labour needed for manual application of fertilizers.
- The fertilizer applicator is durable as it is produced by durable plastic material.
- The fertilizer applicator can be adjusted to apply different doses or volume of fertilizers.

How to use the Fertilizer Applicator

- Assemble all the parts of the fertilizer applicator. You can read the instruction manual to see how the parts will be assembled.
- Open the cover on the top of the machine; fill up the fertilizer applicator container by pouring dry fertilizer.
- Calibrate the equipment and set the right volume of fertilizer you want the fertilizer applicator to apply to plants.
- Put the fertilizer applicator on your back. The equipment is like a knapsack bag that can be carried on the back.
- Place the fertilizer applicator tube at the base of each plant and apply the right dose of fertilizer to the plant.
- Repeat this step for all plants.

What to Consider When Choosing the Best Fertilizer Spreader?

When choosing the best fertilizer spreader, there are several factors to consider ensuring you select the right model for your needs.

- Size: The size of the spreader is an important consideration, as it will determine how much material you can spread at one time.

- Type of material: Some spreaders are designed to spread granular fertilizer and lime, while others are better suited for seed or liquid applications.
- Spreading pattern: The spreading pattern of the spreader can vary depending on the design of the discharge mechanism.
- Adjustability: The ability to adjust the application rate and spreading pattern is an important feature to look for in a fertilizer spreader.
- Durability
- Ease of use
- Price

Self-check 3	**Written test**

Directions: Answer all the questions listed below.

Part I. write true if the statement if correct false if not

1. Soil testing is an important step in determining the nutrient requirements for soil health and fertility improvement.
2. Soil amendments are not necessary for soil health and fertility improvement in crop production.

Part II. Choose the correct answer from the following alternatives

1. Which of the following factors should be considered when determining the requirements for soil health and fertility improvement for crop production?
   a) Soil nutrient levels c) Organic matter content
   b) Soil pH d) All of the above
2. Which of the following can be used to improve soil health and fertility?
   a) Organic fertilizers c) Cover crops
   b) Inorganic fertilizers d) All of the above
3. When determining the requirements for soil health and fertility improvement, what should be considered regarding the specific nutrient needs of the crops?
   a) Nutrient deficiencies c) Nutrient uptake by crops
   b) Nutrient ratios d) All of the above

Part III: Short Answer Questions

1. What are some common indicators of soil health that should be considered during the assessment process?
2. Explain the significance of organic matter content and soil structure in soil health and fertility improvement.
3. What role does pH and soil acidity or alkalinity play in determining soil health and fertility requirements?

Operation Sheet 3.1: measuring agronomic use efficiency

Objective: To assess the efficiency of nutrient or input use in agricultural practices by calculating agronomic use efficiency.

Materials Needed:

- Yield data (harvested crop weight or volume)
- Input data (amount of fertilizer, water, or other inputs used)
- Calculator

Procedure:

Step 1 Gather Yield Data:

- Collect the yield data for the specific crop or field of interest.
- Note the harvested crop weight or volume for the area under consideration.

Step 2 Collect Input Data:

- Identify the inputs to be evaluated for agronomic use efficiency, such as fertilizer, water, or other relevant inputs.
- Gather the data on the amount or quantity of inputs applied to the crop or field.

Step 3 Calculate Agronomic Use Efficiency:

- Determine the agronomic use efficiency metric that aligns with the input being assessed. Common metrics include:

a. Nutrient Use Efficiency (NUE):

- Calculate NUE by dividing the yield achieved by the amount of nutrient input applied.
- NUE (%) = (Yield / Nutrient Input) x 100

b. Water Use Efficiency (WUE):

- Calculate WUE by dividing the yield achieved by the amount of water input applied.
- WUE (kg/m³ or L/kg) = Yield / Water Input

c. Input Use Efficiency:

- Calculate input use efficiency by dividing the yield achieved by the amount of specific input applied.
- Input Use Efficiency (%) = (Yield / Input) x 100

Step 4 Interpret and Analyze Results:

- Evaluate the calculated agronomic use efficiency values.
- Compare the results with historical data, regional averages, or defined benchmarks to assess the effectiveness of input use.

Step 5 Identify Factors Influencing Efficiency:

- Analyze the factors that might have influenced the agronomic use efficiency results.
- Consider factors such as soil conditions, climate, crop variety, management practices, and input application methods.

Step 6 Document and Report:

- Record the agronomic use efficiency calculations and the corresponding input and yield data.
- Document any observations, insights, or factors influencing the efficiency results.
- Prepare a report summarizing the agronomic use efficiency findings, including any recommendations for improvement.

https://www.youtube.com/watch?v=2MaZvkyPu_I

Operation Sheet 3.2: Calculate Nutrients and Water Required for Crop

Objective: To calculate and optimize nutrient and water management for crop production, ensuring efficient resource use and maximizing yields.

Equipment and Materials:

- Soil sampling equipment (e.g., soil auger, soil corer)
- Water measuring tools (e.g., rain gauge, soil moisture meter)
- Laboratory services for soil and water analysis
- Crop-specific nutrient recommendation guidelines
- Fertilizer calculator
- Personal protective equipment (PPE)

Procedure:

Step 1 Crop and field assessment

- Conduct a thorough assessment of the target crop(s) and the field.
- Identify soil types, assess nutrient levels, and consider environmental factors.

Step 2 Soil Sampling and Analysis:

- Use appropriate soil sampling equipment to collect soil samples from various locations within the field or plot.
- Collect samples at the recommended soil depth (e.g., 0-20 cm) for nutrient analysis.
- Send the collected soil samples to a laboratory for analysis of nutrient content, pH, organic matter, and other relevant parameters.
- Record the results obtained from the laboratory analyses.

Step 3 Determine Crop Nutrient Requirements:

- Obtain crop-specific nutrient recommendation guidelines from reputable sources or local agricultural extension services.
- Identify the nutrient requirements for the target crop at different growth stages (e.g., planting, vegetative, flowering, fruiting).
- Consider factors such as soil nutrient status, crop yield goals, and nutrient uptake efficiency when determining nutrient requirements.

Step 4 Calculate Nutrient Application Rates:

- Use the soil test results and crop nutrient requirement guidelines to calculate the nutrient application rates.
- Take into account the nutrient sources already present in the soil and adjust the fertilizer application rates accordingly.
- Utilize a fertilizer calculator or software to determine the precise amounts of fertilizers needed based on nutrient content and desired application rates.

Step 5 Water Monitoring and Analysis:

- Monitor and record the amount of water received through rainfall or irrigation.
- Use water measuring tools such as rain gauges or soil moisture meters to track water availability and soil moisture levels.
- Consider crop water requirements at different growth stages and adjust irrigation practices accordingly.

Step 6 Determine Crop Water Requirements:

- Identify the target crop's water requirements at various growth stages based on literature, crop-specific guidelines, or expert advice.
- Consider factors such as climatic conditions, soil type, crop evapotranspiration rates, and irrigation system efficiency.

Step 7 Calculate Irrigation Water Application Rates:

- Calculate the irrigation water application rates based on the crop's water requirements and the available water supply.
- Determine the irrigation scheduling and frequency based on soil moisture levels, weather conditions, and crop water needs.
- Optimize irrigation practices to minimize water loss due to evaporation, runoff, or deep percolation.

Step 8 Implement Nutrient and Water Management Plan:

- Apply the calculated nutrient application rates at the appropriate growth stages and using recommended fertilization methods (e.g., basal, top-dressing).

- Monitor soil nutrient levels periodically to ensure nutrient adequacy and make necessary adjustments if deficiencies or excesses occur.
- Implement the calculated irrigation water application rates using appropriate irrigation methods and scheduling techniques.

https://www.youtube.com/watch?v=n7ZZF2ff2CQ

Operation sheet 3.3: Calculate nutrient budgeting

Objective: To determine the nutrient requirements and fertilizer recommendations for a specific crop based on nutrient budgeting.

Materials Needed:

- Soil test results (including nutrient levels, pH, and organic matter content)
- Crop nutrient requirement guidelines or recommendations
- Calculator

Procedure:

Step 1 Gather Soil Test Results:

- Collect recent soil test results for the specific field or area where the crop will be grown.
- Note the nutrient levels, pH, and organic matter content in the soil test report.

Step 2 Identify Crop Nutrient Requirements:

- Refer to crop nutrient requirement guidelines or recommendations specific to the crop being grown.
- Identify the optimal nutrient levels or ranges for key nutrients required by the crop (e.g., nitrogen, phosphorus, potassium).

Step 3 Determine Nutrient Deficiencies or Excesses:

- Compare the nutrient levels from the soil test results with the crop's nutrient requirement guidelines.
- Identify any nutrient deficiencies or excesses in the soil based on the recommended nutrient ranges.

Step 4 Calculate Nutrient Removal by the Crop:

- Determine the expected yield of the crop in terms of weight or volume per unit area (e.g., kilograms per hectare or pounds per acre).
- Refer to crop-specific nutrient removal rates to estimate the amount of nutrients that will be taken up by the crop during its growth cycle.

Step 5 Assess Nutrient Availability in the Soil:

- Consider the nutrient availability in the soil based on the soil test results and the specific crop's ability to access nutrients.
- Account for factors such as pH, organic matter content, and nutrient interactions that may affect nutrient availability.

Step 6 Calculate Fertilizer Recommendations:

- Determine the nutrient requirements to meet the crop's needs by accounting for nutrient deficiencies, crop nutrient removal, and nutrient availability in the soil.
- Calculate the amount of fertilizer needed to supply the required nutrients, considering the nutrient content of the chosen fertilizer product(s).

Step 7 Adjust for Fertilizer Efficiency and Application Timing:

- Consider the fertilizer efficiency or utilization rate, which can vary depending on the fertilizer type, soil conditions, and crop characteristics.
- Adjust the fertilizer recommendations to account for the expected efficiency and timing of fertilizer application (e.g., split applications).

Step 8 Document the Nutrient Budget:

- Record the nutrient budget calculations, including the nutrient deficiencies or excesses identified, crop nutrient requirements, and fertilizer recommendations.
- Include details such as the specific nutrients, fertilizer types, application rates, and timing.

Step 9 Implement and Monitor:

- Apply the recommended fertilizers according to the calculated nutrient requirements and application timing.
- Monitor the crop's nutrient status throughout the growing season, conducting periodic plant tissue analysis or soil testing if needed.
- Adjust the fertilization program as necessary based on monitoring results and crop response.

https://www.youtube.com/watch?v=O6-0VIsoxDU

LAP test -3

Name……. ID……..

Date…….

Time started: _____ Time finished: _____

Instructions: Given necessary templates, tools and materials you are required to perform the following tasks within **3** hour. The project is expected from each student to do it.

Task 1: You are required to perform measure agronomic use efficiency

Task 2: You are required to perform Calculate Nutrients and Water Required for Crop

Task 3: You are required to perform Calculate nutrient budgeting

LG #4	LO #4: Implement agro ecology, principles and elements in production systems

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics:

- Diversity of agro ecology
- Knowledge of agro ecological practices
- Selection of synergy components for climate change
- Implementation of resource-use efficiency
- Recycling of nutrients, biomass and water
- Understanding organic matter, pest and disease
- Principles and element of agro ecology

This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Understand Diversity of agro ecology
- Understand Knowledge of agro ecological practices
- Select synergy components for climate change
- Implement resource-use efficiency
- Identify Recycling of nutrients, biomass and water
- Understand organic matter, pest and disease
- Understand Principles and element of agro ecology

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below.
3. Read the information written in the information Sheets
4. Accomplish the Self-checks

Information Sheet 4

4.1. Diversity of agro ecology

Agroecology is sustainable farming that works with nature. Ecology is the study of relationships between plants, animals, people, and their environment and the balance between these relationships. Agroecology is the application of ecological concepts and principals in farming. It is a holistic and integrated approach that simultaneously applies ecological and social concepts and principles to the design and management of sustainable agriculture and food systems.

Agroecological systems are highly diverse. From a biological perspective, agroecological systems optimize the diversity of species and genetic resources in different ways. For example, agroforestry systems organize crops, shrubs, livestock and trees of different heights and shapes at different levels or strata, increasing vertical diversity. Intercropping combines complementary species to increase spatial diversity. Crop rotations, often including legumes, increase temporal diversity. Crop–livestock systems rely on the diversity of local breeds adapted to specific environments. In the aquatic world, traditional fish polyculture farming, Integrated Multi-Trophic Aquaculture (IMTA) or rotational crop-fish systems follow the same principles to maximizing diversity.

Increasing biodiversity contributes to a range of production, socio-economic, nutrition and environmental benefits. By planning and managing diversity, agroecological approaches enhance the provisioning of ecosystem services, including pollination and soil health, upon which agricultural production depends. Diversification can increase productivity and resource-use efficiency by optimizing biomass and water harvesting.

Agroecological diversification also strengthens ecological and socio-economic resilience, including by creating new market opportunities. For example, crop and animal diversity reduces the risk of failure in the face of climate change. Mixed grazing by different species of ruminants reduces health risks from parasitism, while diverse local species or breeds have greater abilities to survive, produce and maintain reproduction levels in harsh environments. In turn, having a

variety of income sources from differentiated and new markets, including diverse products, local food processing and agri-tourism helps to stabilize household incomes.

Consuming a diverse range of cereals, pulses, fruits, vegetables and animal-source products contributes to improved nutritional outcomes. Moreover, the genetic diversity of different varieties, breeds and species is important in contributing macronutrients, micronutrients and other bioactive compounds to human diets.

Agroecology is the application of ecological concepts and principals in farming. Agroecology promotes farming practices that;

- Mitigate climate change - reducing emissions, recycling resources and prioritizing local supply chains.
- Work with wildlife - managing the impact of farming on wildlife and harnessing nature to do the hard work for us, such as pollinating crops and controlling pests.
- Put farmers and communities in the driving seat - they give power to approaches led by local people and adapt agricultural techniques to suit the local area - and its specific social, environmental and economic conditions.

4.2. Knowledge of agro ecological practices

Agroecology is an integrated approach that simultaneously applies ecological and social concepts and principles to the design and management of food and agricultural systems. It seeks to optimize the interactions between plants, animals, humans and the environment while taking into consideration the social aspects that need to be addressed for a sustainable and fair food system.

Agroecology is “the application of ecological concepts and principles to the design and management of sustainable agroecosystems,” also reflected by the Food and Agriculture Organization (FAO) in stating that: “Agroecological innovations apply ecological principles – such as recycling, resource use efficiency, reducing external inputs, diversification, integration, soil health and synergies, for the design of farming systems that strengthen the interactions between plants, animals, humans and the environment for food security and nutrition.

The focus of agroecology was further broadened to include a food systems focus a few years later, encompassing alternative and local food networks, consumer-producer relationships, social agricultural networks, agri-food systems, food markets, and food procurement, leading to "an integrated discipline that includes elements from agronomy, ecology, sociology and economics." Agroecology has since gone beyond an interdisciplinary approach to embrace a trans-disciplinary focus, seeking transformative solutions to real world problems in the development of sustainable food systems, while striving towards inclusive engagement of all stakeholders in knowledge generation.

There is no definitive set of practices prescribed as agroecological. It is easier to discuss practices as being more or less agroecological, depending on the extent to which they make use of ecological processes as opposed to external inputs; they are equitable, environmentally friendly, locally adapted and owned; and they are integrated within a systems approach, rather than focusing on single measures. Agroecological farming emphasizes diversification, mixed cultivation, intercropping, cultivar mixtures, and habitat management techniques for crop-associated biodiversity, biological pest control, improvement of soil structure and health, biological nitrogen fixation, and the recycling of nutrients, energy, and "waste" as inputs to the production process.

4.3. Selection of synergy components for climate change

Synergy is defined as the interaction of adaptation and mitigation so that their combined effect is greater than the sum of their effects if implemented separately. Synergy is achieved if the outcome from interactions between the two interventions is greater than that gained from having the interventions act independent of each other.

Synergies between mitigation and adaptation

Mitigation refers to activities aimed at reducing greenhouse gases (GHG) and preventing further GHG emissions. Adaptation: are activities directed towards developing/enhancing coping strategies and resilience to climate change effects, particularly among vulnerable communities. Despite these two interventions being closely interrelated, international framework

on climate change has provided for mitigation and adaptation as two separate entities with more focus being placed on mitigation. Synergy is a key means through which mitigation and adaptation efforts as well as benefits can be leveraged to ensure efficiency and effectiveness in climate change action.

How does Agroecology contribute to climate change adaptation?

Three key dimensions of adaptation can be drawn out. These are:

i. Resilience, the ability to withstand climate impacts (shocks caused by extreme events) with more resilient agricultural systems clearly being better adapted;
ii. The process of adaptation (adjusting in response to a changing environment); and
iii. The state of "being adapted", the extent to which an agricultural system is well suited to current conditions, including the current uncertainty, which tends to increase as climate variability increases.

Typical climate change adaptation options in agriculture include:

- Use of different varieties or species;
- New cropping practices, (e.g., different timing of planting);
- Greater use of water conservation and management technologies;
- Diversification of on-farm activities;
- Enhancement of agrobiodiversity;
- Adapted livestock and pasture management;
- Improved management of pests, diseases, and weeds; and
- Better use of short-term and seasonal climate forecasting to reduce production risks.

Field Level Practices

The key combined effects of rising temperatures, increasingly variable and unpredictable rainfall, and higher frequency of extreme weather events, such as droughts and floods that farmers already have to adapt to, include:

- Reduced access to water;
- Shorter growing seasons;

- Longer water deficit periods during crop growth (increased number of days without rain combined with higher potential evapotranspiration);
- Reduced availability and nutritional quality of animal fodder at key times; and
- Accelerating land degradation (because of higher temperatures) and changes in the distribution of insects and pathogens.

Identified seven categories of agroecological practices contributing to adaptations that were related to:

- Preventing land degradation;
- Improving soil health;
- Better water management;
- Diversifying production;
- Adaptive crop management;
- Pest and disease control; and
- Managing livestock.

4.4. Implementation of resource-use efficiency

Resource use efficiency is a measure of how effectively resources such as land, water, energy, and labor are used in agricultural production. It is an important concept in sustainable agriculture as it can help to reduce the negative environmental impacts of agriculture while maximizing productivity and profitability.

There are several ways in which resource use efficiency can be improved in agriculture:

- Water use efficiency: Water is a critical resource in agriculture, and improving water use efficiency is essential for sustainable agricultural production. This can be done through practices such as drip irrigation, rainwater harvesting, and the use of drought-resistant crops.
- Energy use efficiency: Agriculture is a significant user of energy, and improving energy use efficiency can help to reduce greenhouse gas emissions and minimize costs. This can be done through practices such as the use of renewable energy sources and the adoption of energy-efficient technologies.

- Land use efficiency: Land is a limited resource, and improving land use efficiency is essential for sustainable agricultural production. This can be done through practices such as intercropping, crop rotation, and agroforestry, which help to maximize the use of land and reduce the need for external inputs.
- Labor use efficiency: Labor is a critical resource in agriculture and improving labor use efficiency can help to reduce costs and improve productivity. This can be done through practices such as the use of labor-saving technologies and the adoption of appropriate labor management practices.

Improving resource use efficiency in agriculture can have several benefits, including:

- Reduced environmental impact: By improving resource use efficiency, the negative environmental impacts of agriculture such as soil erosion, water pollution, and greenhouse gas emissions can be minimized.
- Improved productivity: By using resources more efficiently, productivity can be increased, leading to higher crop yields and improved profitability.
- Cost savings: Improving resource use efficiency can lead to cost savings by reducing the need for external inputs such as fertilizers and pesticides.
- Improved sustainability: By improving resource use efficiency, the sustainability of agricultural production can be enhanced, ensuring that resources are available for future generations.

4.5 Recycling of nutrients, biomass and water

4.5.1 Recycling of nutrients

A nutrient cycle is defined as the cyclic pathway by which nutrients pass-through, in order to be recycled and reutilized. The pathway comprises cells, organisms, community and ecosystem. In the process, nutrients get absorbed, transferred, released and reabsorbed. It is a natural recycling system of mineral nutrients.

Nutrients consumed by plants and animals are returned to the environment after death and decomposition and the cycle continues.

Soil microbes play an important role in nutrient recycling. They decompose organic matter to release nutrients. They are also important to trap and transform nutrients into the soil, which can be taken up by plant roots. Nutrient cycling rate depends on various biotic, physical and chemical factors. Examples of a nutrient cycle: carbon cycle, nitrogen cycle, water cycle, oxygen cycle, etc.

Energy Flow and Nutrient Cycle

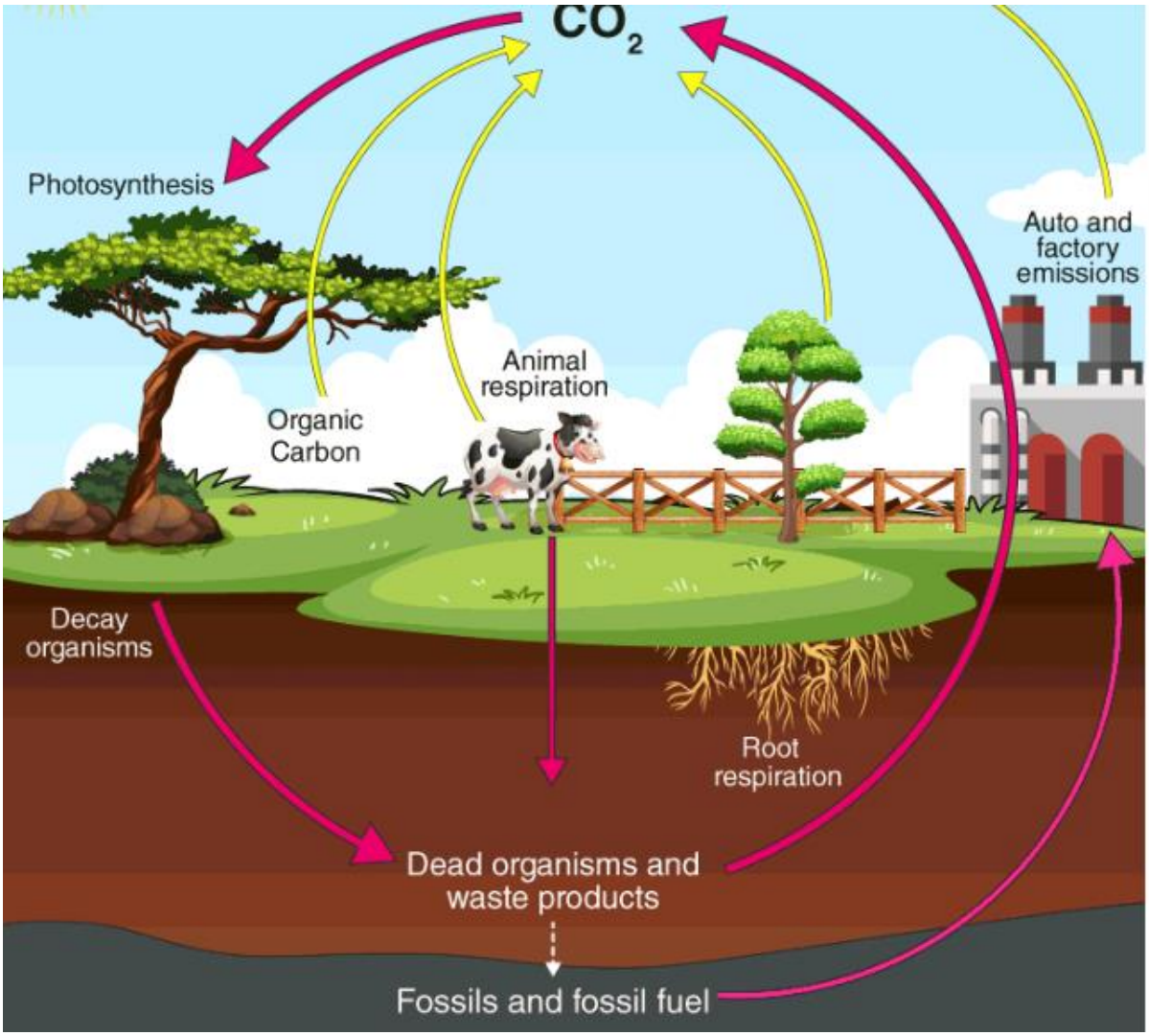
How nutrient cycling differs from energy flow?

The energy flow refers to the transfer of energy from one trophic level to another in the food chain and food web. It is unidirectional and energy is lost from one trophic level to another in the form of heat. Sunlight is the ultimate energy source.

Nutrient cycling is a cyclic process that encompasses the movement of nutrients from the physical environment to living organisms and back to the environment. Nutrients are present on the earth where they are recycled, transformed into different forms and reutilized. Nutrient Cycle Examples: Nutrient recycling involves both biotic and abiotic components. The main abiotic components are air, water, soil. Recycling of Carbon, Hydrogen, Nitrogen and Oxygen occurs in water, air and soil, whereas calcium, phosphorus, potassium, etc. are recycled mainly in soil and are available locally.

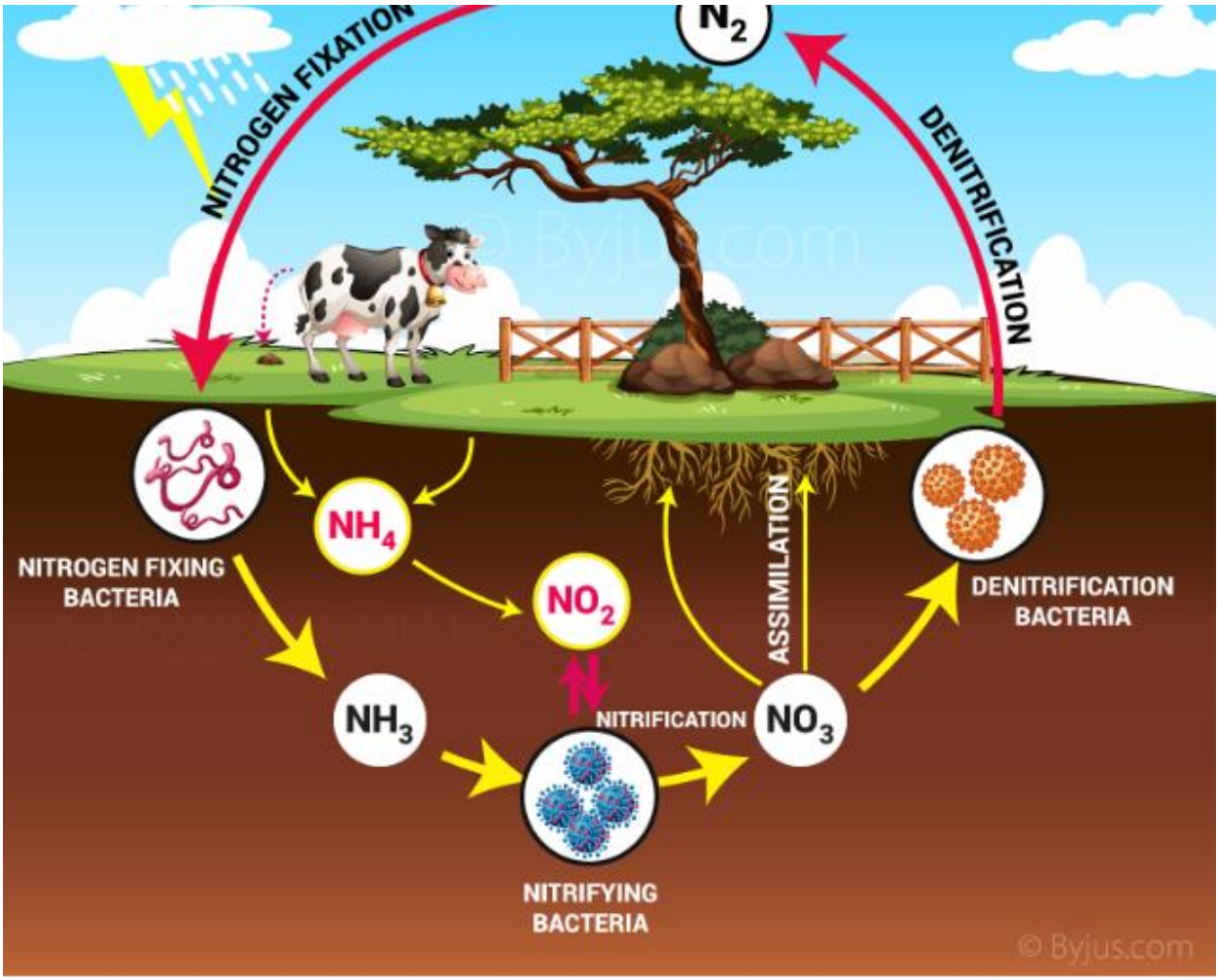
The 4 main nutrient cycles are:

A. Carbon Cycle: Carbon is the main constituent of all the living cells. All the organic matter and biomolecules contain carbon.



- Carbon is present mainly as carbon dioxide and methane in the atmosphere
- There is a continuous exchange of carbon between biotic and abiotic components by the process of photosynthesis and respiration
- Atmospheric carbon dioxide is fixed by plants in the process of photosynthesis
- All the living organisms release carbon dioxide during respiration
- Carbon is released into the atmosphere by burning of fossil fuels and auto emissions
- Organic carbon from dead and decaying organisms and waste products is released into the atmosphere after decomposition

B. Nitrogen Cycle: Nitrogen is also an essential component of life. Nitrogen cannot be directly utilized by living organisms and has to be converted to other forms.



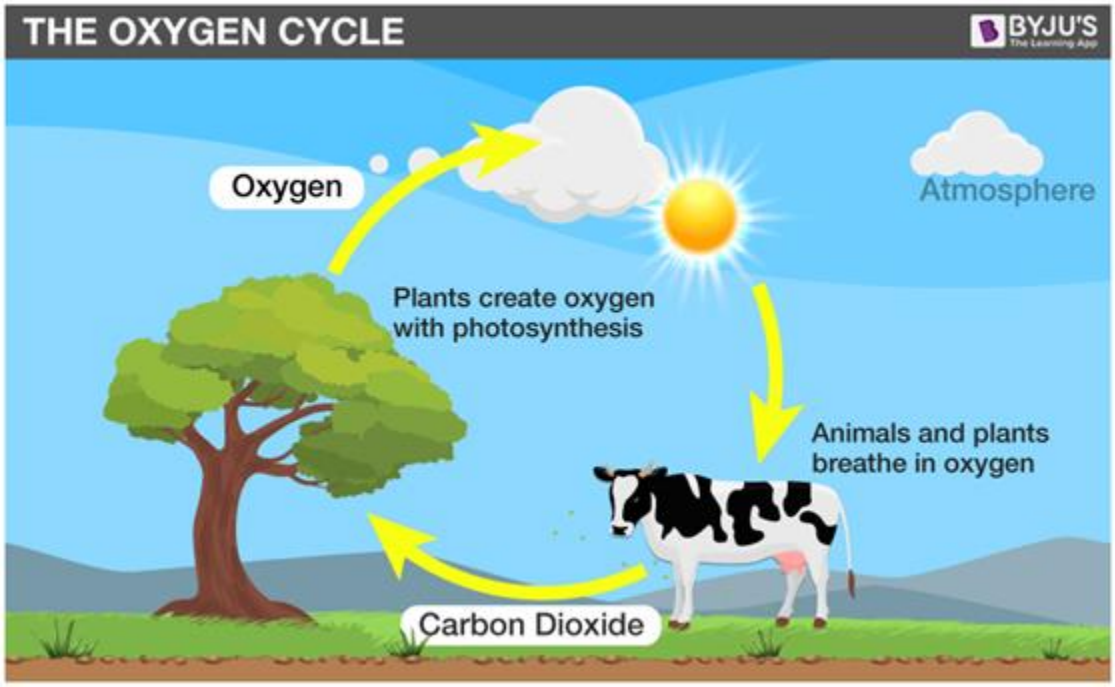
- By the process of nitrogen fixation, nitrogen-fixing bacteria fix atmospheric nitrogen to ammonia and nitrifying bacteria convert ammonia to nitrate. It is then taken up by plants
- Atmospheric nitrogen is converted to nitrates directly by lightning and assimilated by plants
- Decomposers break down proteins and amino acids of dead and decaying organic matters and waste product
- Denitrifying bacteria convert ammonia and nitrates to nitrogen and nitrous oxide by the process of denitrification. In this way, nitrogen is released back into the atmosphere

C. Oxygen Cycle

Oxygen is essential for life. Aquatic organisms are dependent on oxygen dissolved in water. Oxygen is required for decomposition of biodegradable waste products.

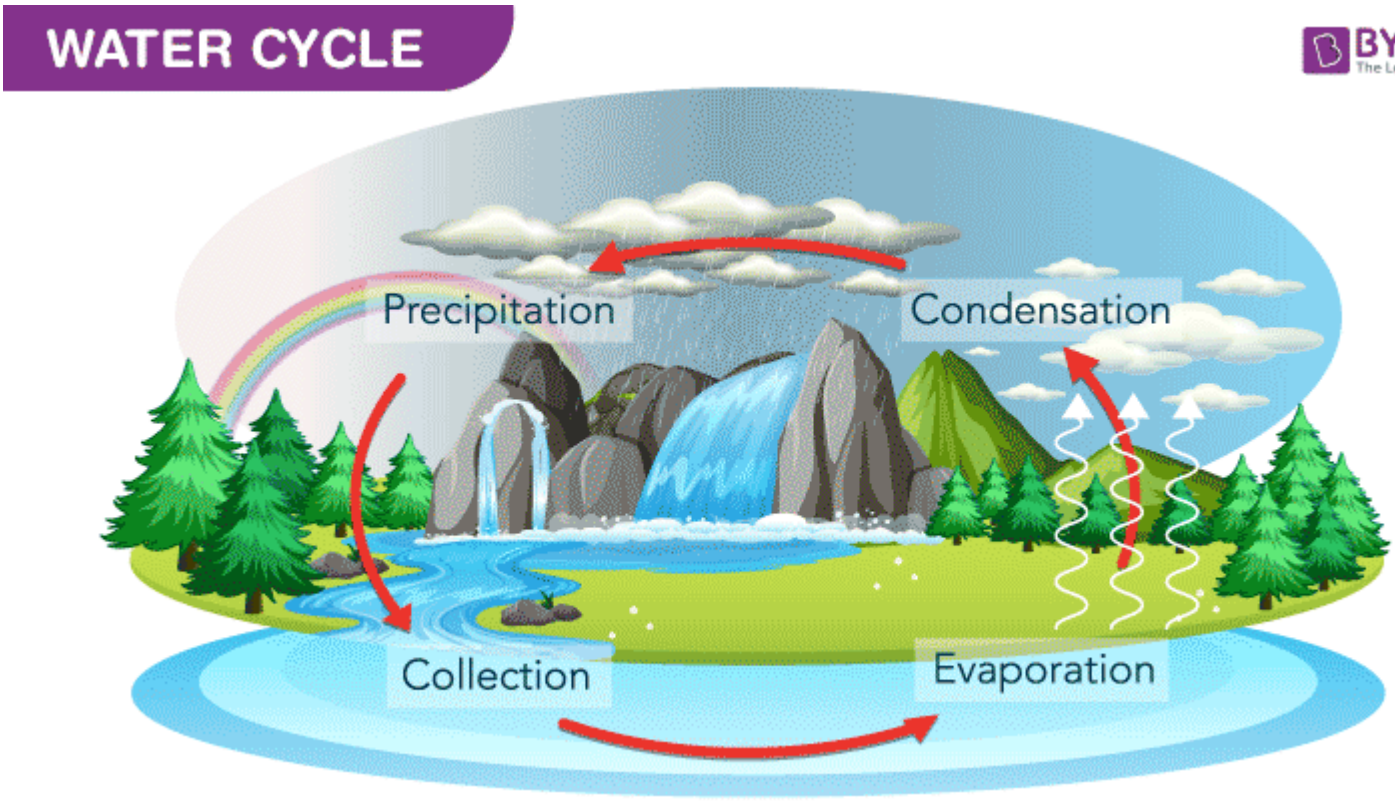
- Photosynthesis is the main source of oxygen present in the atmosphere

- Atmospheric oxygen is taken up by living organisms in the process of respiration and release carbon dioxide which is used for photosynthesis by plants



D. Hydrologic or Water Cycle: Water is an essential element for life to exist on earth.

- Water from oceans, lakes, rivers and other reservoirs is continuously converted to vapour by the process of evaporation and transpiration from the surface of plants
- Water vapours get condensed and return by precipitation and the cycle continues
- The water falling on the ground is absorbed and stored as groundwater



Importance of Nutrient Cycling

All living organisms, biomolecules and cells are made up of carbon, hydrogen, oxygen, nitrogen, sulphur and phosphorus. These elements are essential for life. It is important to recycle and continuously replenish nutrients into the environment for life to exist.

Nutrient cycling is important for:

- It is required for the transformation of nutrients from one form to another so that it can be readily utilized by different organisms, e.g. plants cannot take atmospheric nitrogen and it has to be fixed and converted to ammonium and nitrate for uptake.
- Transfer of nutrients from one place to another for utilization, e.g. air to soil or water
- Nutrient cycles keep the ecosystem in equilibrium and help in storing nutrients for future uptake
- Through nutrient cycling, living organisms interact with the abiotic components of their surroundings

4.5.2 Recycling biomass

Recycling of biomass refers to the process of converting organic waste materials, such as agricultural residues, food scraps, and forest residues, into useful products or energy sources. It is an environmentally sustainable approach that utilizes the organic matter present in biomass to create value while reducing waste and greenhouse gas emissions.

The recycling of biomass offers several benefits:

- Waste Reduction: Biomass recycling diverts organic waste from landfills, reducing the amount of waste that would otherwise decompose and produce methane, a potent greenhouse gas.
- Resource Recovery: By recycling biomass, valuable resources such as nutrients, carbon, and energy can be recovered and reused, contributing to a circular economy.
- Renewable Energy Generation: Biomass can be converted into various forms of renewable energy, including biogas, biofuels, and biomass-based electricity. These energy sources can substitute for fossil fuels, reducing dependence on non-renewable resources and lowering greenhouse gas emissions.
- Soil Improvement: Recycling biomass as organic amendments, such as compost or biochar, can enhance soil fertility, structure, and water-holding capacity. It improves nutrient cycling, reduces soil erosion, and promotes healthier plant growth.
- Sustainable Agriculture: Biomass recycling provides a sustainable source of nutrients and organic matter for agricultural practices. By returning organic residues to the soil, it reduces the reliance on synthetic fertilizers and promotes soil health and long-term productivity.
- Biochemical and Biobased Products: Biomass recycling can be utilized to produce biochemicals and biobased materials, such as bioplastics, biofibers, and bioadhesives, which offer environmentally friendly alternatives to petroleum-based products.

To effectively recycle biomass, various technologies are employed, including composting, anaerobic digestion, pyrolysis, and gasification. These processes convert biomass into different end products, such as compost, biogas, biofuels, heat, or electricity, depending on the specific technology and feedstock used.

4.5. Understanding organic matter, pest and disease

4.5.1. Understanding organic matter

Soil organic matter is the fraction of the soil that consists of plant or animal tissue in various stages of breakdown (decomposition). Most of our productive agricultural soils have between 3 and 6% organic matter. Soil organic matter contributes to soil productivity in many different ways.

Organic matter is made up of different components that can be grouped into three major types:

i. Plant residues and living microbial biomass.
ii. Active soil organic matter also referred to as detritus.
iii. Stable soil organic matter, often referred to as humus.

The living microbial biomass includes the microorganisms responsible for decomposition (breakdown) of both plant residues and active soil organic matter or detritus. Humus is the stable fraction of the soil organic matter that is formed from decomposed plant and animal tissue. It is the final product of decomposition.

The first two types of organic matter contribute to soil fertility because the breakdown of these fractions results in the release of plant nutrients such as nitrogen, phosphorus, potassium, etc. The humus fraction has less influence on soil fertility because it is the final product of decomposition (hence the term “stable organic matter”). However, it is still important for soil fertility management because it contributes to soil structure, soil tilth, and cation exchange capacity. This is also the fraction that darkens the soil’s color.

Benefits of Stable Soil Organic Matter

There are numerous benefits to having a relatively high stable organic matter level in an agricultural soil. These benefits can be grouped into three categories:

Physical Benefits

- Enhances aggregate stability, improving water infiltration and soil aeration, reducing runoff.

- Improves water holding capacity.
- Reduces the stickiness of clay soils making them easier to till.
- Reduces surface crusting, facilitating seedbed preparation.

Chemical Benefits

- Increases the soil's CEC or its ability to hold onto and supply over time essential nutrients such as calcium, magnesium and potassium.
- Improves the ability of a soil to resist pH change; this is also known as buffering capacity.
- Accelerates decomposition of soil minerals over time, making the nutrients in the minerals available for plant uptake.

Biological Benefits

- Provides food for the living organisms in the soil.
- Enhances soil microbial biodiversity and activity which can help in the suppression of diseases and pests.
- Enhances pore space through the actions of soil microorganisms. This helps to increase infiltration and reduce runoff.

Over time, the application and incorporation of organic materials can result in an increase in stable soil organic matter levels. Sources of organic materials include: Crop residues, Animal manure, Compost, Cover crops, Perennial grasses and legumes.

Organic Matter Management

Farm practices that help to maintain or increase soil organic matter levels:

- Use of conservation tillage practices (for example zone tillage or no-till). Tillage exposes the organic matter to air and will result in the lowering of stable organic matter due to increased mineralization rates and erosion losses.
- Rotation of annual row crops with perennial grass or legume sods will reduce erosion and build up organic matter as a result of the decomposition of the rootmass.

- Establishment of legume cover crops will enhance organic matter accumulation by providing the N needed for decomposition of freshly added organic materials, especially those with a high C to N ratio (corn stover, cereal straw, heavily bedded manure, etc.).
- Avoiding soil compaction which increases waterlogging, and maintaining proper pH to enhance microbial activity and decomposition of freshly added materials.

1.6.2. Understanding pest

How Organic Pest Management Works Pest management in organic systems necessarily relies on preventing pest problems from becoming economically damaging. Prevention, in turn, relies on maintaining vibrant and healthy soil ecology, as well as supporting biodiversity above ground through diverse rotations, providing habitat for beneficial organisms, and reducing habitat for pests. When preventative measures, which include physical and cultural controls, are not able to control pest populations, the option of last resort is the use of allowed pesticides.

Regular monitoring of your crop will provide information about the status of both pest and beneficial populations. It is important to be able to identify which critters are pests, which are beneficial, and which are “neutral,” as well as the various life stages of pests and beneficial and what they eat. Organic pest management may include the use of pheromone traps, release of beneficial insects, use of trap crops, and other organically approved techniques.

Organic Pest Management Basics Healthy soils are the basis of good pest management because they support plant health and resilience—the ability of the plant to recover from pest damage. If possible, plant cultivars that are resistant to some of the main pests (diseases, nematodes, and insects) in your area. Correct identification of pest damage early in the cropping cycle is important, so that effective options can be considered to reduce pest populations and damage. Insects can also be disease vectors, so recognizing the symptoms of common (insect-vectored) diseases and knowing your organic management options is valuable. Knowledge of the lifecycles of important pests can provide an early warning if large numbers of egg masses or immature forms of the pest are observed when monitoring.

Exclusion—keeping a pest out of a field, bed, hoop house or greenhouse—is a useful concept in organic production, particularly for hard-to-manage soil-born pests (i.e., phytophthora and nematodes) and insect pests. Clean equipment and tools can help prevent soil pests from inadvertently spreading from one field to another. To prevent insect infestations, use good screening at doors and vents of hoop houses and greenhouses.

If treatment with an organically approved pesticide becomes necessary, remember that these are most effective when plant surfaces are well covered. Sufficient pressure, combined with appropriate nozzle selection and positioning, will promote good coverage.

Useful Tools for Pest Management

- Develop a small library of pest-management reference materials.
- Identify local experts (entomologists, plant pathologists, soil scientists) who are willing to respond quickly to questions.
- Learn major pests (and their natural enemies!) of your main crops, understand their lifecycles, and learn how to use a hand lens. Train other workers on your farm on pest and damage ID, as well.
- Take digital pictures of unknown pests/ plant symptoms and send them to local experts for identification.
- Have at least a good-quality backpack sprayer; larger farmers may want to have a tractor-based spray rig with internal agitation.

Organic Regulations Relating to Pest Management The organic standard for crop pest, weed and disease management specify the following:

a. The producer must use management practices to prevent crop pests, weeds, and diseases including but not limited to: i. Crop rotation and soil and crop nutrient management practices

ii. Sanitation measures to remove disease vectors, weed seeds, and habitat for pest organisms; and iii. Cultural practices that enhance crop health, including selection of plant species and varieties with regard to suitability to site-specific conditions and resistance to prevalent pests, weeds, and diseases.

b. Pest problems may be controlled through mechanical or physical methods including but not limited to:

i. Augmentation or introduction of predators or parasites of the pest species;

ii. Development of habitat for natural enemies of pests;

iii. Nonsynthetic controls such as lures, traps, and repellents.

c. Weed problems may be controlled through:

i. Mulching with fully biodegradable materials;

ii. Mowing;

iii. Livestock grazing;

iv. Hand weeding and mechanical cultivation;

v. Flame, heat, or electrical means; or

vi. Plastic or other synthetic mulches: Provided that, they are removed from the field at the end of the growing or harvest season.

d. Disease problems may be controlled through:

i. Management practices which suppress the spread of disease organisms; or

ii. Application of nonsynthetic biological, botanical, or mineral inputs.

e. When the practices provided for in paragraphs

a. through d. of this section are insufficient to prevent or control crop pests, weeds, and diseases, a biological or botanical substance or a substance included on the National List of synthetic substances allowed for use in organic crop production may be applied to prevent, suppress, or control pests, weeds, or diseases: Provided, That, the conditions for using the substance are documented in the organic system plan.

f. The producer must not use lumber treated with arsenate or other prohibited materials for new installations or replacement purposes in contact with soil or livestock.

Organic pest control methods

Integrated Pest Management (IPM) is an environmentally conscious approach to managing insects, weeds and disease. By focusing on natural processes, growers use pest control methods beginning with the least toxic and amplifying the pest control needs gradually if problems persist. The six steps of IPM include:

- Correct identification of damage and responsible pests.
- Know your pest and plant life cycle and biology.
- Monitor and sample for pest population.
- Establish acceptable damage threshold.
- Decide on appropriate management technique.
- Evaluate results. Of these six critical steps, deciding on a control method for minimizing pest disturbance is key.

These control methods can be both preventative and reactive, and can be broken down into their own four tactical categories: Cultural, Mechanical & Physical, Biological, and Chemical. These tactical categories have been laid out purposely from least harmful to the environment, to most likely to cause damage to biological ecosystems.

1.6.3. Understanding disease

Understanding plant diseases requires knowledge of pathogen biology, disease cycles, symptom recognition, transmission mechanisms, environmental factors, and effective management strategies. Plant diseases are caused by a variety of organisms, including fungi, bacteria, viruses, nematodes, and other microorganisms. They can affect all parts of a plant, including leaves, stems, roots, flowers, and fruits.

Here are key points to consider when understanding plant diseases:

- Pathogens: Different pathogens have distinct characteristics and modes of infection. Fungi often cause diseases such as powdery mildew and rust, while bacteria can lead to bacterial blight or soft rot. Viruses are microscopic entities that require a host plant to reproduce and can cause diseases like mosaic or leaf curl. Nematodes are microscopic worms that can damage roots, leading to stunted growth and nutrient deficiencies.
- Disease Development: Plant diseases typically involve a sequence of steps known as the disease cycle. It includes the pathogen's survival and dissemination, infection of susceptible plant tissues, colonization and multiplication within the host, and production of new inoculum to infect other plants. Understanding the disease cycle helps identify critical points for intervention and disease management strategies.

- Symptoms: Plant diseases exhibit a range of symptoms, including wilting, leaf spots, discoloration, deformities, stunting, fruit rot, and general decline. Recognizing and accurately diagnosing symptoms are essential for determining the cause of the disease and implementing appropriate control measures.
- Disease Spread: Plant diseases can spread through various mechanisms, including wind, water, insects, animals, contaminated tools, and infected plant material. Understanding the modes of transmission and spread is crucial for implementing preventive measures, such as crop rotation, sanitation practices, and the use of disease-free planting material.
- Environmental Factors: Environmental conditions play a significant role in disease development. Temperature, humidity, rainfall, and other climatic factors can influence pathogen growth, reproduction, and the susceptibility of host plants. Understanding the relationship between environmental conditions and disease development helps predict disease outbreaks and implement appropriate management strategies.
- Disease Management: Effective disease management involves integrated approaches that combine cultural practices, genetic resistance, biological control, chemical control (fungicides, bactericides), and other preventive measures. Integrated Pest Management (IPM) strategies aim to minimize the use of chemical inputs and promote sustainable practices while considering economic feasibility.

4.7. Principles and element of agro ecology

4.7.1. Principles of agro ecology

There are 13 principles of agro ecology

- Recycling: Preferentially use local renewable resources and close, as far as possible, resource cycles of nutrients and biomass
- Input reduction: Reduce or eliminate dependency on external inputs.
- Soil health: Secure and enhance soil health and functioning for improved plant growth, particularly by managing organic matter and by enhancing soil biological activity.
- Animal health: Ensure animal health and welfare.

- Biodiversity: Maintain and enhance diversity of species, functional diversity and genetic resources and maintain biodiversity in the agro ecosystem over time and space at field, farm, and landscape scales.
- Synergy: Enhance positive ecological interaction, synergy, integration, and complementarity among the elements of agro ecosystems (plants, animals, trees, soil and water).
- Economic diversification: Diversify on-farm incomes by ensuring small-scale farmers have greater financial independence and value addition opportunities while enabling them to respond to demand from consumers.
- Co-creation of knowledge: Enhance co-creation and horizontal sharing of knowledge, including local and scientific innovation, especially through farmer-to-farmer exchange.
- Social values and diets: Build food systems based on the culture, identity, tradition, social and gender equity of local communities that provide healthy, diversified, seasonally, and culturally appropriate diets.
- Fairness: Support dignified and robust livelihoods for all actors engaged in food systems, especially small-scale food producers, based on fair trade, fair employment, and fair treatment of intellectual property rights.
- Connectivity: Ensure proximity and confidence between producers and consumers through promotion of fair and short distribution networks and by re-embedding food systems into local economies.
- Land and natural resource governance: Recognize and support the needs and interests of family farmers, smallholders, and peasant food producers as sustainable managers and guardians of natural and genetic resources.
- Participation: Encourage social organization and greater participation in decision-making by food producers and consumers to support decentralized governance and local adaptive management of agricultural and food systems.

4.7.2. Elements of Agro ecology

- Efficiency: Innovative agro ecological practices produce more using less external resources.

- Balance: enhanced resilience of people, communities and ecosystems is key to sustainable food and agricultural systems
- Diversity: Diversification is key to agro ecological transitions to ensure food security and nutrition while conserving, protecting and enhancing natural resources.
- Co-creation and sharing of knowledge: Agricultural innovations respond better to local challenges when they are co-created through participatory processes.
- Recycling: More recycling means agricultural production with lower economic and environmental costs.
- Synergies: Building synergies enhances key functions across food systems, supporting production and multiple ecosystem services.
- Human and social values: Protecting and improving rural livelihoods, equity and social well-being is essential for sustainable food and agricultural systems.
- Circular and solidarity economy: Circular and solidarity economies that reconnect producers and consumers provide innovative solutions for living within our planetary boundaries while ensuring the social foundation for inclusive and sustainable development.
- Culture and food traditions: By supporting healthy, diversified and culturally appropriate diets, agro ecology contributes to food security and nutrition while maintaining the health of ecosystems.
- Land/natural resource
- Resilience: Enhanced resilience of people, communities and ecosystems is key to sustainable food and agricultural systems.
- Responsible governance: Sustainable food and agriculture requires responsible and effective governance mechanisms at different scales from local to national to global.

Elements of Agro ecology are interlinked and interdependent.

Self-check 4	Written test

Part I. write true if the statement is correct false if not

1. Agro ecology emphasizes the use of monoculture farming practices to maximize the yield of a single crop species.
2. Agroforestry, an agro ecological practice, involves integrating trees or shrubs into agricultural landscapes to provide ecological and economic benefits.
3. No-till farming, a key principle in agro ecology, involves continuous plowing of the soil to enhance aeration and nutrient availability.
4. Local adaptation is a fundamental aspect of agroecology, emphasizing the need to tailor farming practices to the specific environmental, social, and cultural context of a region.

Part II. Choose the correct answer

1. Which agroecological principle emphasizes the integration of diverse crops and livestock within a farming system to enhance ecological processes and nutrient cycling?
    a. Crop rotation
    b. Monoculture farming
    c. Chemical-intensive agriculture
    d. Hydroponic cultivation
2. In agroecology, what is a key element of promoting biodiversity to enhance natural pest control and improve overall ecosystem resilience?
    a. Monocropping
    b. Pesticide-intensive practices
    c. Agroforestry
    d. Synthetic fertilizer application
3. What agroecological practice involves using cover crops and mulches to improve soil health, reduce erosion, and enhance water retention?
    a. No-till farming
    b. Intensive tillage
    c. Monoculture planting
    d. Conservation agriculture

4. Which agroecological principle emphasizes adapting farming practices to the specific environmental and social conditions of a particular region, promoting local knowledge and community involvement?
   a. Global standardization
   b. Local adaptation
   c. Industrialized agriculture
   d. High-input farming
5. What is a fundamental element of agroecology that involves minimizing the use of external inputs and relying on on-farm resources, such as organic matter and natural nutrient cycling?
   a. Input-intensive agriculture
   b. Sustainable intensification
   c. Low-input farming
   d. Conventional farming practices

Part III: Short Answer Questions

1. What are some key principles of agroecology that guide sustainable farming practices?
2. Describe the role of biodiversity in agroecology and its benefits for production systems.
3. What are some techniques used for natural pest and disease management in agroecological systems?
4. How can farmers implement agroforestry practices to enhance sustainability and resilience in their production systems?

LG #5	LO #5: Document soil health and plant nutrition program and specifications

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics:

- Detailed plan, objectives, specifications and associated costs
- Recording, documenting and reporting agronomic and soil data

This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Understand detailed plan, objectives, specifications and associated costs
- Record, document and report agronomic and soil data

Learning Instructions:

- Read the specific objectives of this Learning Guide.
- Follow the instructions described below.
- Read the information written in the information Sheets
- Accomplish the Self-checks

Information Sheet 5

5.1. Detailed plan, objectives, specifications and associated costs

5.1.1. Detailed plan for documenting the Soil Health and Plant Nutrition Program

The detailed plan for documenting the Soil Health and Plant Nutrition Program involves several key steps. These steps include determining relevant regional data and site characteristics, defining the requirements for plant nutrition, and documenting the soil health and plant nutrition program. The plan should also involve monitoring plant growth and evaluating the program. This may include communicating the soil health and plant nutrition plan, procedures, and schedule of activities to staff, monitoring program implementation and results by testing soil, plants, and produce, and reviewing and refining the program to ensure it is responsive to changing conditions.

The soil health management plan should be a living document that is adapted based on experience and outcomes over time. It is important to consider soil health constraints beyond nutrient deficiencies and excesses, which limit agroecosystem sustainability. The plan should also involve identifying biological and physical constraints in addition to those identified by standard nutrient testing.

Additionally, tools such as the SNAP (Soil Nutrient Assessment Program), a component of the USDA/ARS Soil and Water Hub, can be used to provide an estimate of plant-available nutrients that the soil naturally provides. This web-based tool can help in making soil test fertilizer recommendations and estimating plant-available nutrients.

In summary, the detailed plan for documenting the Soil Health and Plant Nutrition Program should encompass various steps, including defining plant nutrition requirements, documenting the program, and monitoring plant growth and program evaluation. It should also involve adapting the soil health management plan based on experience and outcomes over time, considering soil health constraints beyond nutrient deficiencies, and utilizing tools such as the SNAP program for soil nutrient assessment.

5.1.2. Objectives of Documenting the Soil Health and Plant Nutrition Program

- To create a comprehensive documentation system for the soil health and plant nutrition program.
- To ensure accurate record-keeping of soil testing, nutrient management, and crop nutrition practices.
- To facilitate data analysis and evaluation of the program's effectiveness.
- To provide a reference for compliance with regulatory requirements and demonstrate adherence to best practices.
- To support decision-making and continuous improvement of soil health and plant nutrition management.

5.1.3. Specifications for Documenting the Soil Health and Plant Nutrition Program

Specifications for documenting the Soil Health and Plant Nutrition Program include the development of a detailed plan, objectives, specifications, and associated costs based on program requirements.

The plan should include on-site procedures and scheduled activities required for the program, as well as the identification and costing of resources, tools, equipment, and machinery required for the program.

Additionally, the program should be monitored regularly to evaluate its effectiveness, and the results should be communicated to staff.
The program should also be reviewed and refined to ensure it is responsive to changing conditions.

The specifications should be based on the principles and practices of soil health and plant nutrition, including the characteristics of soil and other growth media types, their uses and additives to enhance available nutrition for specific plants, methods of nutrient uptake by plants, and favorable conditions for effective uptake to occur.

5.1.4. Associated Costs for Documenting the Soil Health and Plant Nutrition Program

Associated costs for documenting the Soil Health and Plant Nutrition Program include the identification and costing of resources, tools, equipment, and machinery required for the program, as well as the cost of soil amendments, management practices, and fertilizer requirements.

Additionally, the Healthy Soils Program Incentive Grants provide financial incentives directly to growers and ranchers to implement conservation management practices, which can help offset some of the costs associated with soil health and plant nutrition programs.

Furthermore, the development of soil health practices, such as cover cropping and no-till farming, has been shown to have potential economic benefits for farmers, including cost savings and improved yields.

5.2. Recording, documenting and reporting agronomic and soil data

Data collection procedures of Agronomic crops

A sample is a small represented part of a population. For example, in order to investigate the plant height of a crop, some plants are selected to collected necessary data. These plants are a sample.

The number of elements selected for a sample is known as the sample size. A sample of size less than 30 is termed as a small sample and that having 30 or more elements is termed as a large sample. Statistic changes with sample size.

Objectives of sampling

- Sampling is more useful for taking timely and quick decision
- It save money
- It ensure the accuracy of results
- It represent population if can be properly done.
- It creates a greater scope.

- Large population problems can be avoided

Methods of selecting a sample are called sampling.

Sampling may be of following types:

a. Simple Random Sampling
b. Stratified random sampling
c. Purposive sampling
d. Systematic sampling
e. Cluster sampling
f. Multistage sampling
g. Double sampling
h. Area sampling
i. Quota sampling

1.2.1. Recording, documenting and reporting agronomic or crop data

- Phonological observation: Date of sowing, emergence, floral initiation, anthesis, physiological maturity.
- Agronomic observations: The agronomic observations to be recorded at all the phonological stages of crop include plant population, number of leaves/plant, maximum leaf area of individual leaf, LAI, diurnal leaf water potential, diurnal leaf temperature, PAR, plant height, leaf weight, culm weight, dry matter, head/ear weight, grain weight, etc.
- Final grain yield and yield components.

Biometric observations in field crops

It is important to collect data on various growth and yield parameters which may facilitate to interpret the results in a better way. Generally growth parameters such as plant, height, tiller production, leaf area index and dry matter production are recorded. In addition, yield parameters may also be recorded. The growth and yield parameters may be recorded at different growth stages viz. tillering, primodial initiation and flowering and at harvest. Observations can also be taken at 20, 40, 60, 80 and 100 days after planting or sowing. Appropriate methods of

sampling and proper measurement are important to get a valid data. The growth and yield parameters that should be recorded for important field crops are given below:

Wheat

1. Plant height
2. Leaf area index (LAI)
3. Tillers/m row length
4. Effective tillers/m row length
5. Number of spikelets/panicle
6. Number of grains/panicle
7. Test grain weight
8. Grain yield
9. Straw yield

Maize

1. Cobs/plant
2. Cob weight
3. Grains/cob
4. Test grain weight
5. Grain yield
6. Stover yield

Pulses

1. Number of pods/plant
2. Number of grains/pod
3. Weight of pods/plant
4. Test grain weight
5. Grain yield

Rapeseed-mustard

1. Plant height
2. Number of branches/plant
    - Primary

- Secondary
- Tertiary

3. Numbers of siliquae/plant
4. Number of seeds/siliquae
5. 1000 seed weight
6. Seed yield
7. Stover yield

1.2.2. Recording, documenting and reporting Soil data

Soil type, soil depth, structure, texture, water holding capacity, soil profile structure, bulk density, salinity, alkalinity, pH, EC, microbial content, soil fertility, soil productivity, available soil moisture, wilting point, permanent wilting point and available moisture at different stages of crop.

Self-check 5	Written test

Directions: Answer all the questions listed below.

Part I. write true if the statement is correct false if not

1. Documenting soil health and plant nutrition program specifications is essential for maintaining a record of the specific fertilizers used, application rates, and timing throughout the growing season.
2. Documenting the soil health and plant nutrition program is unnecessary when using standardized approaches, as variations in crop response are negligible.

Part II. Choose the correct answer

1. What is the primary purpose of documenting soil health and plant nutrition program specifications?
    a. Administrative convenience
    b. Environmental conservation
    c. Tracking and analysis
    d. Aesthetic presentation
2. Which aspect of the soil health and plant nutrition program should be documented to ensure traceability and informed decision-making?
    a. Local weather patterns
    b. Farmer's personal observations
    c. Crop market prices
    d. Fertilizer types and application rates
3. In the context of documenting the soil health program, why is it important to record soil test results?
    a. To showcase scientific knowledge
    b. To satisfy regulatory requirements
    c. To assess nutrient needs and trends
    d. To compete in agricultural competitions
4. How does documenting the plant nutrition program contribute to sustainable agriculture?
    a. It has no impact on sustainability

b. Facilitates data-driven decision-making
c. Increases water usage
d. Promotes excessive pesticide application

Part III: Short Answer Questions

1. Explain the significance of documenting the chosen soil amendments, fertilizers, and their application rates.
2. Describe the importance of documenting any adjustments or modifications made to the program based on monitoring results.
3. How can farmers document the outcomes and results of the soil health and plant nutrition program, such as crop yields or soil improvement indicators?

LG #6	LO #6: Monitor and evaluate soil health, fertility and crop production program

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics:

- Monitoring soil health, crop production and productivity
- Identifying non-compliance of soil fertility management
- Complying with legislative requirements and codes of practice
- Taking remedial action to improve soil health, fertility and plant nutrition
- Incorporation of feed backs and changes

This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Monitor soil health, crop production and productivity
- Identify non-compliance of soil fertility management
- Comply with legislative requirements and codes of practice
- Take remedial action to improve soil health, fertility and plant nutrition
- Incorporate feed backs and changes

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below.
3. Read the information written in the information Sheets
4. Accomplish the Self-checks

Information Sheet 6

6.1 Monitor soil health, crop production and productivity

6.1.1 Monitor soil health

Soil Health refers to soil functionality and its capacity to deliver ecosystem services and productivity. It is a complex interrelation between physical, chemical and biological properties, all combining to help soil fulfill its key functions. Healthy soils are vital for our food production, for water retention, carbon sequestration, and nutrient cycling, underground and above-ground biodiversity.

Soil quality is the capacity of soils within landscapes to sustain biological productivity, maintain environmental quality and promote plant and animal health. On the other hand, soil health is the 'fitness' (or condition) of soil to support specific uses (e.g. crop growth) in relation to its potential as determined by the inherent soil quality and is more sensitive to anthropogenic disturbance and is severely limited in extreme environments.

Soil Health Indexing: Soil health integrates all components of the soil system and is assessed by indicators that describe and quantify biological, chemical and physical properties. Soil characteristics (Table 6.1) that contribute to a healthy soil include:

- protected soil surface and low erosion rates,
- A reasonable level of soil organic matter (>1%),
- High biological activity and biological diversity,
- Good available moisture storage capacity,
- Favorable soil pH,
- Deep root zone,
- sufficient amount and balanced proportion of available nutrients,
- Resilient and stable soil structure,
- Adequate internal drainage,
- Favorable soil strength and aeration,
- Favorable soil temperature,

- Low levels of soil borne pathogens,
- Low levels of toxic substances

Table 6.1: Assigning values and scores to three scenarios of soil quality indicators

Indicator	*Value and corresponding score (in parenthesis)* *Best*	*Good*	*Poor*	*Remark*
OM, %	3.5-5 (25)	2.5-3.5 (20)	<2 (15)	
Physical properties Water stable aggregation, %	>80 (6)	60-80 (4)	50-60 (2)	
Bulk density (BD), oz/in³	<0.64, <0.81 & <0.92 (6)	0.64<BD<0.74, 0.81<BD <0.92 & 0.92 <BD<0.98 (3)	>0.81, >0.92 & >0.98 (1)	Clayey, silty & sandy soil, respectively
Depth, inch	>40 (4)	20-40 (3)	<20 (2)	Varies with crop
Infiltration rate, in/hr	0.4-2.0, 0.08-1.0 & 0.01-0.1 (4)	± 0.2 of best value (3)	± 0.4 of best value (2)	Sandy/silt, loam & clayey, respectively
Water holding capacity, in/24 in soil	2.4 & 3.5 (5)	1.6-2.4 & 3.5-3.9 (3)	<1.6 & >3.9 (1)	Not desirable if out of "good" range
Chemical properties pH	5.8-7.3 (9)	5.0-5.7, 7.3-8.0 (6)	<5, > 8 (3)	
Fertility (N, P and K)	N-100% of yield goal P&K- 100% sufficient (6)	N-80% of yield goal P&K- 80% sufficient (4)	N-< 80% of yield goal P&K- < 80% sufficient (2)	Based on recommended rate for specific field and crop
CEC, meq/oz soil	14-25 (5)	5-14 (3)	<5 (1)	
EC, dS/m	<0.98 (5)	0.98 - 1.71 (3)	>1.71 (1)	Varies with crop
Soil Biological Properties Microbial biomass oz C/100 lbs soil	0.6-1.1 (9)	0.3-0.6 (6)	<0.3 (3)	4 in top soil
Soil respiration lbs CO_2-C/a/d	32-64 (9)	16-32 (7)	<16, >64 (4)	4 in top soil
Earth worm, #/ft² in holes	> 15 (7)	5-15 (5)	<5 (3)	Population is limited by resource availability

Table 6.2: Total soil quality score and corresponding general recommendation.

Total score	*Intervention type*	*Description*
>90	Minor new intervention; continue with maintenance to avoid degradation	Look for the indicator with lowest score and intervene with appropriate remediation practices
80-90	Moderate intervention	Look for the indicator with lowest score for each component and intervene with appropriate remediation practices.
<80	Major and immediate intervention is required	Investigate the score of indicators in each component and apply comprehensive best management practices. This level of soil quality warrants the need for raising soil organic matter level.

Appendix. Indicator and corresponding potential problems if the indicator is not at desirable level, causes and intervention required to return an indicator to a desirable level.

Soil Property/Indicator	Potential problems	Causes	Intervention
OM	Low OM	Excess tillage, monocropping, residue burning, high harvest index and erosion	Diversify or increase crop rotations, use organic amendments, cover crops, high residue crops and adopt reduced tillage
Soil aggregate Stability	Crusting, erosion and poor infiltration	Low organic matter, compaction and low residue	Adopt conservation tillage, use organic amendments (animal manure, litter, biosolids, mulch, green manure etc), grow cover crops and retain residue cover on soil surface
Bulk Density	Compaction	Heavy traffic, poor aggregation and low soil OM	Avoid working wet soil, reduce traffic, adopt minimum tillage, add organic amendment and diversify cropping systems
Soil depth	Limited root expansion and drainage	Erosion, monocropping, intensive high biomass production and low soil OM	Reduce erosion, add organic amendments, retain crop residue and adopt conservation tillage
Infiltration rate	Poor infiltration	Lack of residue cover, low soil OM, excess Na, poor aggregation, heavy traffic and tillage pan	Diversify or increase crop rotations, add organic amendments, use cover crops and adopt conservation tillage
Water holding capacity	reduced root and plant growth, runoff and nutrient leaching	Low soil OM, conventional tillage, low residue cover, monocropping and heavy traffic	Adopt conservation tillage, crop rotation, cover crops, prescribed grazing and leach out salt
Soil pH	Acidity	Continuous use of inorganic N fertilizers and high harvest index with addition of lime	Add lime for low pH, improve drainage, add OM and add sulfur or alum to reduce pH
Fertility	Poor crop growth and reduced yield	Low soil OM, unbalanced pH, continuous cropping without rotation and reduced stubble return	Add fertilizer and organic amendments
CEC	Low nutrient reserve in the soil and variable pH	Low soil OM, leaching, erosion and high harvest index	Add organic amendments, use cover crops, retain crop residue and exercise crop rotation
EC	Salinity/sodicity	Saline seeps, Saline irrigation water, shallow water table, poor drainage and excess evaporation	Leach excess salts, plant deep rooted crops, grow salt tolerant crops, increase vegetative cover, manage irrigation water and improve drainage
Soil Microbial biomass Soil respiration	Reduced microbial activity in the soil	Low soil OM, high C:N ratio, and sub-optimal soil temperature, moisture and aeration	Agricultural practices that increase soil OM usually enhance soil respiration
Earth worms	Reduced nutrient cycling, impeded drainage and poor aggregate stability	Little or no organic residues in the soil, high/low soil temperature and moisture, and low soil OM	Agricultural practices that increase soil OM usually increase earthworm population

6.1.2 Monitoring crop production and productivity

Crop yield is determined long before the crop sets seed. It is the culmination of how the crop performed during each stage of growth-establishment, seedling growth, tillering/ branching, flowering and grain fill. Monitoring the agronomic factors that are responsible for achieving profitable and sustainable yields is essential to the farmers to improve their competitiveness in an economy that is characterized by escalating costs, variability in grain prices, and diminishing returns. By identifying limitations to crop growth, action can then be taken to address such issues before significant losses occur.

For increasing crop production and profitability crop monitoring allows farmers to be pro-active rather than reactive to factors affecting crop performance. Most farmers carry out some form of

assessment of their farming systems. For example, Assessing weed types and densities may help in deciding the type and concentration of herbicide to be applied, or the number of tillage operations that are to be performed. Final crop yield is a reflection of the effectiveness of the decision-making process and an overall indicator of crop performance.

Benefits of Crop Monitoring

Activities		Benefits
Identify factors that limit crop production and introduce management practices to maximize water use efficiency, crop yield and seed quality.	CROP →	• Identification of major constraints to crop production • Water use efficiency of the crop • Crop yield and profitability
Observe the performance of the crop on the farm and in the neighborhood so as to establish standards for optimum plant density and critical thresholds of insect pests prior to management treatments.	→	• Crop yield and profitability
Tackle specific issues such as diseases, insect pests, weeds, herbicide resistance, nutrient imbalance and decline in soil fertility.	MONITORING →	• Knowledge of major biotic and abiotic constraints as well as potentially important constraints • Knowledge of soil fertility
Evaluate new cropping systems, new crops, and new crop rotations and select appropriate practice for individual fields.		• Knowledge of the crop rotation history of the field • Indication of the sustainability of the cropping system
Discuss and examine new technologies and their integration into the existing farming systems, e.g., zero-tillage and integrated weed management.	→	• Comparison of new technologies with existing practices • Farmers gain confidence in decision-making

Developing a Monitoring Program for Farmers

The degree of sophistication of a monitoring program developed for farmers can vary according to the skills of the farmers, and the time available to them to carry out the field monitoring activities. The group discussion and interaction that follows is also of great benefit to those involved, both farmer and researcher or extension officer.

Field walks and group meetings can be held throughout the year. These meetings provide opportunities for:

- pre-planting discussions (cropping patterns, fertilizer treatments and soil test results);

- reviewing activities undertaken during the year (weed control, management of pests and diseases, and irrigation practices); and
- post-harvest discussion and interpretation of results (introduction of new technology). When field walks and group meetings are conducted, farmers should be encouraged to ask questions, and openly discuss issues with each other and the researcher.

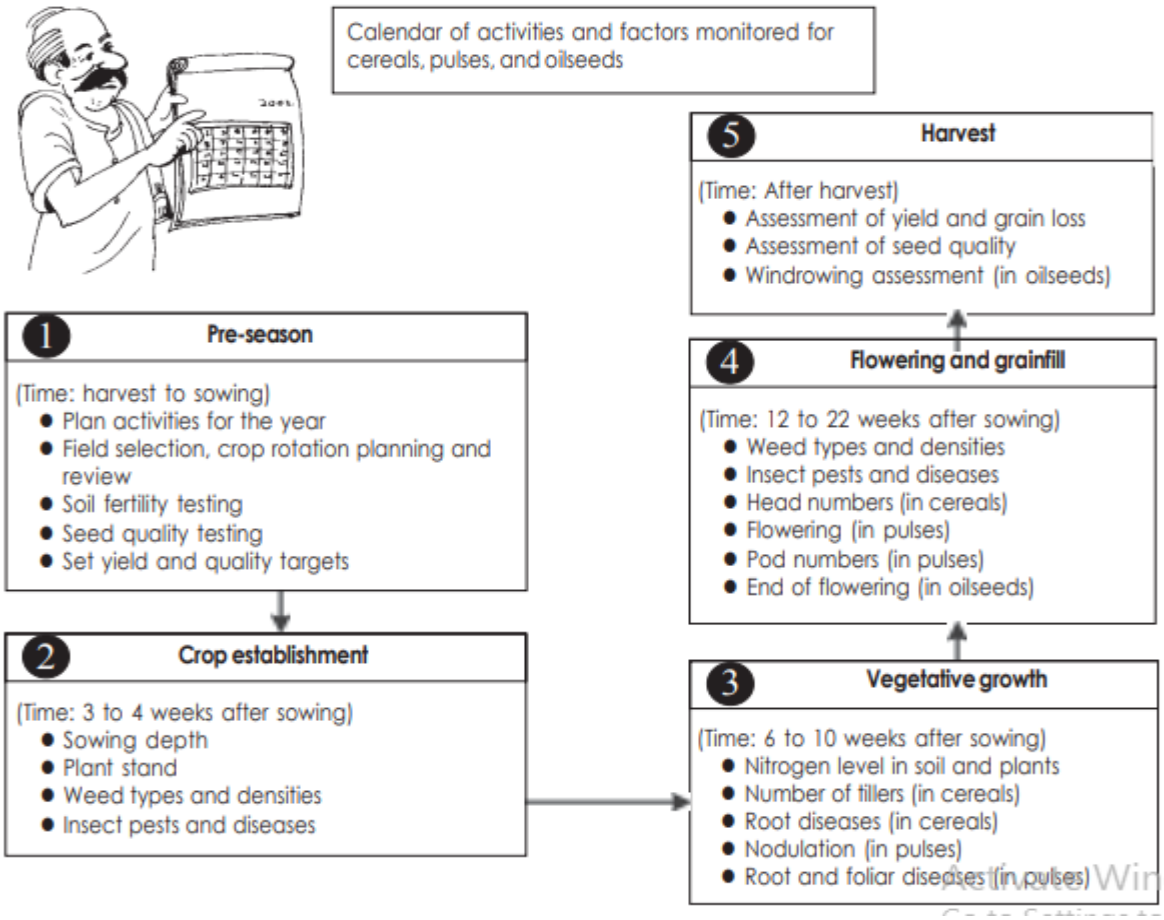


Table 1: Generic Agricultural Productivity Performance Indicators for Title II Food Aid Development activities

Indicator	Data Needed for Measurement	Data on Causal Factors	Measurement Methods	Calculation	Units	Concerns/Issues
1. Harvested crop yields per hectare	Harvested output Area planted	Farm practices Rainfall	Farmer survey Area measurement Rain gauges	Output/area (with reference to rainfall)	Kgs. per hectare	Farmer estimate vs. cropcut Inter- and multiple cropping Economic considerations
2. Gap between actual and potential yields	Harvested output Area planted Demo plot yields	Farm practices Rainfall	Actual (as above) Potential- complete demo plot harvests	(1 - actual/ potential) x 100%	Percent	Harvest yield potential vs. economic maximization ("economic yield gap")
3. Yield variability under varying conditions	Yield time series (pre- and post-activity)	Farm practices Rainfall time series	Methods must be consistent with pre-activity methods	Range or standard deviation. (see Chapter 4.3)	Kgs. per hectare	Difficulty in having consistently collected pre- and post-activity data
4. Value of crop production per household	Harvested output Income from sales Input costs Month stocks run out Prices/inflation rate	Farm practices Rainfall	Farmer survey Market prices (if possible secondary) Rain gauges	(Sales income + monthly cons. x prices-inputs) / (1 + inflation rate)	(Inflation-adjusted) units of money	Different transaction levels Price seasonality/inflation Non-marketed crops Valuing crop by-products Labor costs
5. Months of household food provisions	Month of harvest Month stocks run out Month last tuber harvested	Farm practices Rainfall	Farmer survey Rain gauges	Time between harvest and stock depletion	Number of months	Crop sales, nonfarm income and market food purchases
6. Percent of crop losses during storage	Amount crop stored Amount of crop lost Time in storage	Storage practices Number storage facilities built	Farmer survey Counting/weighing (demo. plots)	Loss rate per time period x amount stored	Percent	Losses in nutrition/quality Differences between demo facilities and actual
7. No. of hectares (or hhs.) with improved practices	List of practices Area (or # of hhs) where practices used	(none)	Farmer survey Area measurement (optional)	(none)	Number hectares or hhs	Partial applications of improved practices
8. Number of crop storage facilities built and used	Number facilities built Number facilities used	(none)	Farmer surveys Project records	(none)	Number of facilities	Volume of facilities Quality of facilities

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6.2 . Identifying non-compliance of soil fertility management

Corrective actions, such as training programs, farmer education, or regulatory measures, may be necessary to address non-compliance and promote sustainable soil fertility management.

- Non-compliance can be observed when farmers apply fertilizers or soil amendments incorrectly, such as using inappropriate application rates, not considering the specific nutrient requirements of crops, or not accounting for soil conditions. These practices can lead to inefficient nutrient uptake by plants or nutrient losses through leaching or runoff.
- Non-compliance may be evident if farmers do not prioritize organic matter management practices, such as inadequate crop residue incorporation, limited use of organic amendments (e.g., compost or manure), or failure to implement cover cropping. Neglecting these practices can result in decreased soil organic matter content and reduced nutrient cycling.

- Non-compliance can occur if farmers do not implement crop rotation or diversification practices. Continuous cultivation of the same crop or limited rotation can lead to increased pest and disease pressure, nutrient imbalances, and decreased soil health.
- Non-compliance may be observed when farmers excessively rely on synthetic fertilizers or agrochemicals without considering integrated pest management practices. Over use of chemical inputs can have detrimental effects on soil health, water quality and biodiversity.

6.3. Complying with legislative requirements and codes of practice

In Ethiopia, compliance with legislative requirements and codes of practice while monitoring and evaluating soil health, fertility, and crop production programs involves several steps and collaborations.

The Ethiopian government's Agricultural Transformation Agency (ATA) has launched the Soil Health and Fertility Ethiopian Soil Information System to address the lack of up-to-date and high-resolution soil information in the country. The CGIAR, through the World Agroforestry Centre, is advising EthioSIS on soil sampling, processing, and analysis procedures, as well as the establishment of soil laboratories.

The Soil Health and Fertility Ethiopian Soil Information System aims to create the most detailed soil map of any country in the world by collecting, analyzing, and cataloging over 100,000 soil samples from 97 sentinel sites across Ethiopia. The soil mapping exercise will involve various teams of soil researchers, who will travel to the sites, collect samples, and transport them to federal and regional labs for analysis. Ethiopian scientists will then develop soil maps using advanced techniques, including soil infrared spectrometry and remote sensing.

To improve soil fertility in Ethiopia, a comprehensive survey and summit meeting were conducted to understand the barriers to agricultural productivity and develop recommendations. The focus regions were West Africa, East Africa, the Great Lakes region, and Ethiopia. The recommendations to improve soil fertility focused on overcoming factors such as nitrogen deficiency, low soil organic carbon content, and phosphorus deficiency.

Organic farming is also an option to ensure sustainable land use and improve soil fertility in Ethiopia. In conclusion, to comply with legislative requirements and codes of practice while monitoring and evaluating soil health, fertility, and crop production programs in Ethiopia, the government has launched the EthioSIS, which involves a comprehensive soil mapping exercise and collaboration with international organizations like the CGIAR.

Additionally, addressing soil fertility issues through organic farming and implementing recommendations from comprehensive surveys can help improve soil health and agricultural productivity in the country.

6.4.Taking remedial action to improve soil health, fertility and plant nutrition

6.4.1. Taking remedial action to improve soil health

Healthy soils come through making the right land management choices. To encourage soil organisms large and small, it is necessary first to protect their habitat. Reduced tillage, avoiding compaction, providing permanent soil cover, using crop rotations and minimizing chemical inputs will all help provide a favorable environment.

Reduced or no tillage systems not only prevent physical damage to the organisms themselves, but slow the rate of organic matter decomposition and concentrate plant debris near the surface horizons where they can be incorporated into the soil by earthworms and fungal translocations. This benefits other microorganisms, promotes soil structure and enhances water storage which in turn improves crop yield and quality. For example, improved soil structure allows deeper and easier root penetration which makes the crop less susceptible to drought stress. There is also a fuel saving to the farmer resulting from fewer passes needed to establish crops.

Cultural control techniques such as creating stale seed beds can help reduce the need for in crop herbicides and crop rotations are an important tool in reducing the buildup of soil borne spores of fungal root diseases reducing the need for fungicides. With increasing concern over herbicide resistant weeds, cultural methods are once again seen as important. A temporary ungrazed grass-legume mix provides an opportunity to reduce blackgrass by allowing it to germinate and then

mowing it as often as needed to prevent seeding. A 4-5 year ley is most effective but a ley of 2 years can still be beneficial.

6.4.2. Taking remedial action to improve soil fertility and plant nutrition

Increasing soil fertility using manure, fertilizer, tillage, irrigation, and other such measures is referred to as ‘acquired fertility'. These strategies have gained in popularity since the 1920s, with remedies such as horn manure, silica, clay, and organic compost being used by Rudolf Steiner to improve soil fertility. Since then, diverse strategies have emerged to improve soil fertility.

Improving Soil Fertility through Nutrient Supplies

Traditionally, farmers have targeted the nutrient supply of soil through direct or indirect methods to improve soil fertility. Critical micronutrients for plant growth and development include iron (Fe), boron (B), manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mo), chlorine (Cl), and nickel (Ni).

Environmental Enhancers and Future Methods to Improving Soil Fertility

The most common form of fertilizer that has minimal disruption to soil systems remains the addition of organic matter, which promotes a healthy and fertile soil and helps improve soil structure. For instance, green manure and the addition of legumes amidst crop systems helps fix nitrogen. Beyond organic matter, some strategies also rely on micro-dosing fertilizer to replenish losses from plant uptake.

Other strategies to improve soil fertility on larger and temporal scales also include crop rotations, increasing crop diversity and richness by avoiding monocultures, and the use of biological pest controls to avoid the use of pesticides or insecticides. In turn, such methods provide longer-term soil fertility whilst maintaining crop productivity.

6.5. Incorporation of feed backs and changes

Incorporating feedback and making changes during the monitoring and evaluation process of soil health, fertility, and crop production programs is essential for improving outcomes and achieving

desired goals. Monitoring and evaluation provide valuable information about the effectiveness of implemented strategies and help identify areas for improvement.

- Regular Monitoring: Regular monitoring is crucial to assess the current status of soil health, fertility, and crop production. It involves collecting data on key indicators such as soil nutrient levels, organic matter content, pH, crop yields, pest and disease incidence, and overall plant health. Monitoring should be conducted at appropriate intervals throughout the growing season and across multiple years to capture variations and trends.
- Data Analysis and Evaluation: The collected data should be thoroughly analyzed and evaluated to identify patterns, trends, and potential areas of concern. Statistical analysis and comparison with predefined targets or benchmarks can provide insights into the performance of the program. Evaluation should consider both qualitative and quantitative aspects, including farmer feedback, expert observations, and scientific evidence.
- Identification of Strengths and Weaknesses: Based on the evaluation results, strengths and weaknesses of the soil health, fertility, and crop production program can be identified. Determine which aspects are performing well and contributing to positive outcomes, as well as areas that require improvement or adjustment. This may include identifying specific practices, inputs, or management strategies that are effective or problematic.
- Stakeholder Engagement: Engaging stakeholders, including farmers, agronomists, researchers, and extension services, is crucial in the feedback and decision-making process. Gather input from those directly involved in implementing and benefiting from the program. Stakeholders' perspectives can provide valuable insights and practical knowledge that may influence the changes and adjustments needed.
- Adaptation and Modification: Based on the evaluation findings and stakeholder input, make informed decisions to adapt and modify the soil health, fertility, and crop production program. This may involve adjusting nutrient management practices, amending soil amendments, altering irrigation schedules, implementing pest and disease control measures, or adopting new technologies. Changes should be based on evidence-based practices and supported by scientific research.
- Documentation and Communication: Document the changes made, along with the reasons behind them, to maintain a record of the program's evolution. Communicate the changes to

all relevant stakeholders to ensure a shared understanding and facilitate their implementation. Clear communication channels among stakeholders are essential to foster engagement, support, and cooperation in implementing the program changes.

Self-check 6	Written test

Directions: Answer all the questions listed below.

Part I. write true if the statement is correct false if not

1. Crop yield is the sole indicator for evaluating the success of a crop production program, and other factors such as soil health and nutrient cycling can be overlooked.
2. Sustainable agriculture practices consider not only economic factors but also the social and environmental impacts of farming activities.
3. Monitoring and evaluating a soil health and fertility program is a time-consuming process that adds unnecessary complexity to agricultural management.

Part II. Choose the correct answer

1. What is a primary purpose of monitoring and evaluating a soil health, fertility, and crop production program?
   a. Compliance with regulations
   b. Aesthetic improvement
   c. Timely adjustments and improvements
   d. Reduction of biodiversity
2. In assessing soil health, which method provides real-time information about moisture levels, aiding in irrigation management?
   a) Soil respiration testing
   b) Soil texture analysis
   c) Soil moisture sensors
   d) Crop rotation mapping
3. When evaluating crop production programs, what is a key metric for assessing nutrient use efficiency?
   a. Total rainfall
   b. Crop yield per unit of applied fertilizer
   c. Number of crop varieties
   d. Soil compaction level

4. In the context of evaluating soil health, what is a common indicator of improved microbial activity and nutrient cycling?
    a. Increased soil compaction
    b. Decline in organic matter content
    c. Decreased crop diversity
    d. Enhanced soil respiration

Part III: Short Answer Questions

1. What are some key parameters and indicators that should be monitored to assess soil health?
2. How can farmers assess crop performance and yield as part of the program evaluation?
3. Explain the significance of monitoring pest and disease incidence and their impact on crop production.
4. What are some techniques and tools used to monitor water availability and irrigation efficiency in the program?

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The experts who developed the learning guide

No	Name	Educational background	Qualification	College	Phone number	E-mail
1	**Dabi Kebede**	Agronomy	MSc	Agarfa	0922685140	dhabik@gmail.com
2	Eyob Birhane	Agronomy	MSc	Alagie	0913047105	yeroosaan@gmail.com
3	Tefera Merga	Plant protection	MSc	Holleta	0956052325	tafemerga@gmail.com
4	Isa Ibrahim	Agronomy	MSc	Gewane	0917388460	isaibrahim67@gmail.com
5	Muftah Mohammed	Horticulture	MSc	Mizan	0979729703	muftahkawo@gmail.com