UNIT 1
INTRODUCTION SOIL FERTILITY MANAGEMENT

Pengenalan Unit

Soil Fertility Management refers to the efficient use of nutrients sources in the soil system. Efficient soil management is the key to sustainable agriculture. Soil fertility research and management is primarily concerned with the essential plant nutrients, their amounts, availability to plants, chemical reactions that they undergo in the soil, loss mechanisms, processes making them unavailable to crop plants and ways and means of replenishing them in these soils.

Objektif Unit

1. Understand issues surrounding nutrient management in agriculture
2. Name essential nutrients required by plants
3. Identify forms in which plants take up the nutrients from the soil
4. Indicate the principles of soil testing and plant analyses
5. State soil and plant sampling techniques and analysis

TOPIK

1.1 Introduction soil fertility management
   a) Soil fertility management
   b) Essential nutrients

1.2 Principles and measurement of soil fertility
   a) Objective of Soil Testing
   b) Basic requirements of soil testing
   c) Primary challenges for sustaining soil fertility
1.3 Soil sampling and analysis
   a) Soil sampling
   b) Taking a representative sample
   c) Methods of soil sampling
   d) Soil analyses
   e) Interpreting Results to Make a Recommendation

1.4 Sampling and plant tissue analysis
   a) Plant sampling
   b) Plant tissue analyses
   c) Sample preparation
   d) Interpretation of Data from Plant Analyses

Isi-isi Penting

1. Soil fertility
2. Essential nutrients
3. Sustaining soil fertility
4. Soil testing
5. Plant testing
6. Nutrient interpretation

Pemerhatian/Pandangan/Pendapat
Kesimpulan Unit Tersebut

1. Soil Fertility Management refers to the efficient use of nutrients sources in the soil system.
2. Plants require at least 16 essential elements for normal growth and for completion of their life cycle.
3. Soil fertility refers to the quality of the soil that enables it to provide essential chemical elements in quantities and proportions for the growth of plants.
4. Soil testing program involves analysis of the soil physical and chemical properties and evaluation of the soil nutrient-supplying capacity.
5. Soil sampling is the first critical step in a soil testing program.
6. Soil analyses can provide information that is important for maximizing nutrient use efficiency and agricultural productivity.
7. A historical record of soil properties provided by long term soil testing is useful for determining the effectiveness of fertilizer management strategies.
8. The first rule in taking soil samples is to use clean and proper tools.
9. Soil and plant tests involve taking representative samples, laboratory analyses, and interpretation and fertilizer recommendation.
10. An understanding of the accuracy and limitations of individual procedures and of the meaning of soil and plant test results is essential.
11. Interpreting soil analysis values and developing a fertilizer management program, are crop specific and sometimes dependent on additional soil and climatic properties.

Rujukan Tambahan (jika ada)


Latihan 1 / Aktiviti 1

1. Discuss precautionary measures when collecting soil samples for micronutrients analysis

Latihan dalam kumpulan 1 / Perbincangan 1

Each group will do the assigned readings and discuss among the members based on a list of questions, issues, statements given in the activity sheet. Selected questions or issues will be presented in class.

1. Read the Brief Notes on: Principles and Measurement of Soil Fertility
3. Review the power point slides located at the class website
4. Your presentation should focus on the following questions or issues:
   a. Definition of soil fertility
   b. What are the objectives of soil testing?
   c. What are the principles of soil testing?
   d. What are the basic requirements of soil testing?

Latihan dalam kumpulan 2 / Perbincangan 2

The class will be divided into groups and each group will do the assigned readings and discussion based on a list of questions, issues, statements given in the activity sheet. Selected questions or issues will be presented in class.

1. Read the Brief Notes on: Soil and Plant Sampling and Analysis
3. Review the power point slides located at the class website
4. Your presentation should focus on the following questions or issues:
   a. Understanding soil sampling procedures and methods
   b. How do you get a representative soil sample?
   c. Understanding soil chemical analysis
Jawapan Latihan 1

1. Use stainless steel auger
2. Collect soil cores in a clean plastic pail. Galvanized pails will contaminate the samples with zinc, which will make the analytical results for micronutrients unusable. Avoid pails that have contained sanitizers or detergents

Jawapan Latihan Dalam Kumpulan / Perbincangan

1. **Soalan 4:** See lecture notes
2. **Soalan 3:** See lecture notes
Introduction to Malaysian Agriculture

- Malaysia has progressed from an economy dependent on agriculture and primary commodities to a manufacturing-based, export-driven economy spurred on by high technology, knowledge-based and capital-intensive industries.
- To move the country forward, the Government has crafted a framework comprising four pillars to drive the change.
- International trade plays a large role in Malaysian economy. Malaysia's main exports constitute electrical and electronics products (more than 50% of total exports). It is also a big exporter of crude oil, liquefied natural gas, palm oil and natural rubber.
- Malaysia also sends abroad chemicals, machinery, appliances and manufactures metals. Main export partners are: United States, Singapore, European Union and Japan.
- The industry is traditionally capital, management, knowledge, labor and infrastructure intensive.
- Stagnating yields and rising production costs, shortage of workers: skilled and unskilled are major threats.
- Roundtable Sustainable Palm Oil (RSPO) was formed in 2004 with the objective: to promote the growth and use of sustainable oil palm products through credible global standards and engagement of stakeholders.
Introduction to Soil Fertility Management

Soil Fertility Management refers to the efficient use of nutrients sources in the soil system. Efficient soil management is the key to sustainable agriculture. Soil fertility research and management is primarily concerned with the essential plant nutrients, their amounts, availability to plants, chemical reactions that they undergo in the soil, loss mechanisms, processes making them unavailable to crop plants and ways and means of replenishing them in these soils.

**Essential Nutrients**

Plants require at least 16 essential elements for normal growth and for completion of their life cycle. The essential nutrients are divided into three categories:

- **Carbon (C), hydrogen (H) and oxygen (O):** They are basic non-mineral elements supplied by air and water and form the basis of all organic compounds.
- **Nitrogen (N), phosphorus (P) and potassium (K):** These are the primary macronutrients and the ones most often in short supply in soils. Plants need relatively large amounts of these nutrients and are the ones most frequently supplied to plants in fertilizers.
- **Calcium (Ca), magnesium (Mg), and sulfur (S):** These are the secondary macronutrients. They are required in smaller amounts than the primary nutrients.
- **Iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mo), boron (B), chlorine (Cl) and nickel (Ni):** These are the micronutrients. These elements occur in very small amounts in both soils and plants, but their role is equally as important as the primary or secondary nutrients. A deficiency of one or more of the micronutrients can lead to severe depression in growth, yield, and crop quality.

<table>
<thead>
<tr>
<th>FUNCTION</th>
<th>DEFICIENCY SYMPTOM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NITROGEN</strong></td>
<td>Symptons of N deficiency are general chlorosis of lower leaves (light green to yellow), stunted and slow growth, and necrosis of older leaves in severe cases.</td>
</tr>
<tr>
<td>Nitrogen (N) is taken up by plants as nitrate (NO$_3^-$) or ammonium (NH$_4^+$) ions. Nitrogen is needed by plants for the production of proteins, nucleic acids (DNA and RNA), and chlorophyll.</td>
<td></td>
</tr>
<tr>
<td><strong>PHOSPHORUS</strong></td>
<td>Slow growth, purplish coloration on foliage of some plants (older leaves first) and poor fruit or seed development.</td>
</tr>
<tr>
<td>Phosphorus (P) is taken up by plants as ortho-phosphate H$_2$PO$_4^-$ or HPO$_4^{2-}$. P plays a major role in energy storage and transfer as ADP and ATP. Aids in root development, flower initiation, and seed and fruit development.</td>
<td></td>
</tr>
<tr>
<td><strong>POTASSIUM</strong></td>
<td>Slow growth, tip and marginal chlorosis, weak stems and stalks and Small fruit or shriveled seeds.</td>
</tr>
<tr>
<td>Potassium (K) is taken up by plants in the form of potassium ions (K$^+$). Potassium is essential for translocation of sugars and for formation of starch. It is required in the opening and closing of stomata by guard cells. Increases plant</td>
<td></td>
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</tbody>
</table>
Potassium increases size and quality of fruits, nuts, and vegetables.

**CALCIUM**

Calcium (Ca) is taken up by plants as the calcium ion (Ca$^{2+}$). A structural nutrient, it is an essential part in cell walls and membranes and is required for the formation of new cells. Ca is not mobile.

- Tip burning of young leaves, death of growing points (terminal buds).
- Premature shedding of blossoms and buds. Weakened stems.

**MAGNESIUM**

Plant uptake of magnesium is in the form of the magnesium ion (Mg$^{2+}$). The chlorophyll molecule, which is essential for photosynthesis. Magnesium (Mg) serves as an activator of many plant enzymes required in growth processes.

- Interverinal chlorosis in older leaves, curling of leaves upward along margins.

**SULPHUR**

Sulphur (S) is utilized in the form of sulfate ions (SO$_4^{2-}$). Sulphur is a constituent of three amino acids (cystine, methionine and cysteine) and is therefore necessary for protein synthesis. It is essential for nodule formation on legume roots.

- Retarded growth rate and delayed maturity. Young leaves light green to yellowish color. In some plants, older tissue may be affected also.

**ZINC**

Zinc (Zn) is taken up by plants as the zinc ion (Zn$^{2+}$) and is an essential constituent of several important enzyme systems in plants. It controls the synthesis of indoleacetic acid, an important plant growth regulator.

- Decrease in stem length and rosetting of terminal leaves. Reduced fruit bud formation.

**IRON**

Iron (Fe) is taken up by plants as ferrous ions (Fe$^{2+}$) and is required for the formation of chlorophyll in plant cells. It serves as an activator for biochemical processes, such as respiration, photosynthesis, and symbiotic nitrogen fixation.

- Interverinal chlorosis of young leaves. Veins remain green except in severe cases. Twig dieback. In severe cases, death of entire limbs or plants

**MANGANESE**

Manganese (Mn) uptake is in the form of the ion Mn$^{2+}$. Manganese serves as an activator for enzymes in plant growth processes. It assists iron in chlorophyll formation.

- Interverinal chlorosis of young leaves. Gradation of pale-green leaf coloration, with darker color next to veins. No sharp color distinction between veins and interveinal areas as with iron deficiency.

**COPPER**

Plant uptake of copper is in the ionic form (Cu$^{2+}$). Copper serves as an activator of growth.
Numerous plant enzymes and plays a role in the development of plant pigments that influence color.

Wilting and eventual death of leaf tips.

**BORON**

Boron (B) is taken up by plants in as boric acid, \( \text{H}_3\text{BO}_3 \). It functions in the differentiation of meristematic cells. Boron is also involved in regulating metabolism of carbohydrates in plants. Nearly all fruiting crops have a high demand for boron in the early fruiting stage.

Death of terminal growth, thickened, curled wilted and chlorotic leaves. Soft or necrotic spots in fruit or tubers. Reduced flowering or improper pollination.

**MOLYBDENUM**

Molybdenum (Mo) is taken up by plants as the molybdate ion \( \text{MoO}_4^{2-} \). It is required by plants for the utilization of nitrogen.

Stunting and lack of vigor. This is similar to nitrogen deficiency, because of the key role of molybdenum in nitrogen utilization. Marginal scorching and cupping or rolling of leaves.

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**PRINCIPLES AND MEASUREMENT OF SOIL FERTILITY**

Soil fertility refers to the quality of the soil that enables it to provide essential chemical elements in quantities and proportions for the growth of specified plants (Brady and Weil, 2002). The major functions of the soil are to provide plants with nutrients, water and oxygen. Soil quality is of fundamental importance for agricultural production, and soil fertility management is increasingly becoming a central issue in the decisions on food security, poverty reduction and environment management.

Soil testing is an important part of nutrient management. Soil tests are used to evaluate soil fertility, which ultimately measures the soil nutrient content. Soil testing program involves analysis of the soil physical and chemical properties and evaluation of the soil nutrient-supplying capacity at the time of sampling. The first rule in taking soil samples is to use clean and proper tools. Soil auger is the most convenient, but a shovel can also be used. Clean and well-labeled containers must be used to store the samples.

**Objectives of Soil Testing**

1. To determine nutrient availability or supply in the soil.
2. To predict probability of obtaining a profitable response to fertilizer.
3. To provide a basis for fertilizer recommendation.
4. To evaluate fertility status of the soil.

**Basic requirements of soil testing**

1. Collection of a representative soil sample
2. Laboratory analyses of the soil sample
3. Interpretation of analytical results
4. Fertilizer recommendations based on interpreted analytical results
Primary challenges for sustaining soil fertility

- Reduce nutrient losses
- Maintain or increase nutrient storage capacity
- Promote recycling of plant nutrients
- Apply additional nutrients in appropriate amounts

Many beneficial agricultural management practices help to maintain nutrient cycling and soil fertility. Example of such practices are: crop rotation, reducing tillage, managing and maintaining crop residue, growing cover crops, composting, liming, applying supplemental fertilizers, etc.

SOIL SAMPLING AND ANALYSIS

Soil Sampling

Soil testing begins with soil sampling. A soil analysis can only be as good as the sample sent to the laboratory. It is important to realize that only a tiny portion of a field is actually analyzed in the laboratory.

Taking a Representative Sample

Sampling is possibly the most neglected step in soil testing, and the greatest source of error in the whole process. Due to the variability in nutrient level from spot to spot it is essential to follow the sampling instructions from the soil testing laboratory. To take a representative soil sample, first we will need to take a minimum of 10-15 soil cores across the defined area in a random pattern, each to the required depth (usually 0-10 cm). These should then be bulked, making up a composite sample from that area. Any parts of the areas that are obviously different (e.g. a gully, a low moist depression, an area where the growth is visibly different, or a raised area with shallow soil) should each be sampled separately.

Methods of Soil Sampling

1. Judgment Sampling
   The researcher judges the color differences: e.g. he may judge a particular shade of color to be typical for a sample at certain sites. Then from these sites, samples are drawn. The accuracy of these samples depends totally on the judgment of the researcher - which may or may not be good.

2. Simple Random sampling
   Simple random sampling is a more precise method of taking soil samples and is less biased by the sampler than judgment sampling. Random sampling is needed where the soil differences are not immediately noticeable by color, texture, etc.

3. Stratified Random sampling
   When stratified random sampling is used, the population, i.e. a field or plot, is divided into sub-populations (strata). For example, the strata may be a ridge, a slope, a low area or a level area. A simple random sample is taken from each stratum.
4. **Systematic Sampling**
Systematic sampling is popular because it is accurate and relatively easy to use. Systematic samples are taken from sites that are equidistant from each other, either in one or two dimensions, forming a grid. **Grid sampling** is done there is variation in the field. Each sample is analyzed separately, so that variability in soil properties can be determined. With data provided by grid sampling maps of soil test values can be constructed from the results. This information can be entered into a geographical information system (GIS) and combined with additional geospatial data.

5. **Composite sampling**
The most common and economical method for sampling an area is composite sampling, where subsamples are collected from randomly selected locations in the field, and the subsamples are composited for analysis. The analytical results from composite sampling provide average values for the sampled area. The actual number of subsamples depends on field size and uniformity. Laboratory analyses are done on this composite or a subsample of it.

Generally, a larger field or a less uniform field should be more intensively sampled than one that is small and uniform. No less than 5 subsamples should be taken, and 15 to 25 are preferred. Ideally, samples should be collected with a soil probe or auger, to the depth of tillage or to the effective rooting depth of plants. Deeper samples may be collected for evaluation of subsoil properties, such as salt or nitrate accumulation. The depth of the sampling is important because the mobility of the nutrients varies with the nutrient content in the different soil zones. The recommended depth for sampling is shown in Table 1.

**Table 1: Recommended sampling depth for soil chemical analysis**

<table>
<thead>
<tr>
<th>Sampling depth (cm)</th>
<th>Soil chemical properties to measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-15</td>
<td>pH, P, K, Cl, S, Ca, Mg, Zn, NH$_4^+$-N, Fe, Mn, Cu, soluble salts</td>
</tr>
<tr>
<td>15-60</td>
<td>NO$_3^-$N, S, Cl</td>
</tr>
<tr>
<td>60-120</td>
<td>NO$_3^-$N</td>
</tr>
</tbody>
</table>
The soil samples should be placed in clean plastic bags. Soil samples should be air-dried or taken to a test laboratory as soon as possible. To dry a soil sample, spread the soil out in a clean, warm, dry area, and let it dry for two to three days. It is best not to heat or dry soil samples in an oven because soil chemical properties may be altered. Bag the sample and send it to a laboratory for analysis. Soil samples can be refrigerated for several days if they cannot be dried immediately.

When soil samples are collected, they need to be dried, ground and sieved prior to analysis. The grinding and sieving operations should ensure a homogeneous mixture for analysis. All samples must be clearly labeled and dated. Collect samples early enough in the cropping cycle to allow results to be used to adjust management practices.

Soil Analyses

Soil test determines the soil’s nutrient supplying capacity by mixing soil for only a few minutes with a very strong extracting solution (often an acid or a combination of acids). The soil reacts with the extracting solution, releasing some of the nutrients. The extractions are accomplished by placing a small measured quantity of soil in a bottle with the extracting agent and shaking the mixture for a certain number of minutes. The solution is filtered and assayed for the concentration of each nutrient. The nutrient concentration is then related to field calibration research that indicates the yield level reached with varying soil nutrient concentrations.

The methods used to test soils vary depending on chemical properties of the soil. For example, tests used for measuring soil P are quite different in the acidic soils than those used in the alkaline soils.
Interpreting Results to Make a Recommendation
Soil test values themselves are mere indices of nutrient-supplying power. They do not indicate the actual amount of nutrients that will be supplied. Many years of field experimentation at many sites are needed to determine which soil test level indicates a low, medium or high capacity to supply the nutrient tested. Recommendations for nutrient applications take into consideration practical knowledge of the plants to be grown, the characteristics of the soil under study and other environmental conditions. The interpretation of soil test data is best accomplished by experienced and technically trained personnel. In most commercial soil test laboratories, the factors to be considered in making fertilizer recommendations are programmed into a computer, and the interpretation is printed out for the farmer's use.

SAMPLING AND PLANT TISSUE ANALYSIS

Plant Sampling

Different plant species may require different tissue parts for meaningful sampling and interpretation. A list of recommended sampling procedures (Jones and Case 1990, Jones et. al 1971) is reproduced in Table 2-1. To ensure a representative sample, sample as many plants as practical. Careful sampling ensures the effectiveness of plant analysis as a diagnostic tool. For major crops, best indicator samples have been identified by stage of growth. For young seedlings, the entire plant is sampled 2.5 cm above the soil level. For larger plants, the most recent fully expanded or mature leaf is the best indicator of nutritional status. They should be taken just prior to or at the onset of flowering. Do not collect tissue that is covered with soil or dust. Do not collect from plants that are damaged by insects, mechanically injured, or diseased. Dead plants or senescent tissues should not be sampled. Also, sampling is not recommended when plants are under moisture or temperature stress. Samples must be protected from dirt and fertilizer materials and should be placed in clean plastic bags.

Plant Tissue Analyses

Plant tissue analysis is a laboratory determination of the total elemental content of plants or of certain plant parts. It is used for a variety of purposes including monitoring the nutrient status of crops and troubleshooting problem areas. It also serves as the basis for nutrient recommendations for perennial fruit crops. When using plant tissue analysis information from a laboratory, you need to use interpretive guidance in order to determine the nutrient status categories.

Producers of high-value crops such as oil palm may need to conduct plant tissue as part of a monitoring program that also includes soil testing. Plant tissue analysis can confirm the adequacy of all nutrients or identify an inadequacy of one or more nutrients. Plant tissue samples should be collected from the correct plant part at the appropriate stage of development.
Sample preparation

Samples are cleaned, placed in an oven at 60°C for at least 12 hours, then ground to pass a 2-mm sieve with a Wiley mill. A 0.50 g sample is dry-ashed in a porcelain crucible for 4 –6 hours at 500°C in a muffle furnace. (If the ashing is judged incomplete, then the ash is cooled, dissolved in 1 M nitric acid, evaporated to dryness, then ashed again for 1 hour.) The residue is dissolved in 25 mL of 1 M hydrochloric acid.

Interpretation of Data from Plant Analyses

When using plant tissue analysis information from a laboratory, one needs to use interpretive guidance in order to determine the nutrient status categories. Figure 1 is a graphical depiction of interpretive guidance for a generic crop. The nutrient concentration ranges (% or ppm) for each nutrient status category and the shape of the growth curve will change for each crop.

Figure 2: An illustration of the meaning of plant tissue analysis interpretive terminology.

Adapted from Australian Soil and Plant Analysis Council Inc. 1997.

The concentration of the essential elements in plants is expressed on a dry-matter basis as either percent or grams per kilogram (g/kg) for the major elements, and either parts per million (ppm) or milligrams per kilogram (mg/kg) for the micronutrients, the units selected depending on the system of use.

There are three major methods of interpreting plant analysis results. They include the use of critical values, sufficiency ranges, and ratios. Most advisory services use sufficiency ranges for primary interpretation. Ratios and DRIS analysis are generally used as secondary and supportive evaluations.
- **Critical Values**
  Critical values have been defined as the concentration at which there is a 5–10% yield reduction. The use of critical values for practical interpretation has limited value. It is best suited to diagnose severe deficiencies and has little application in identifying hidden hunger.

- **Sufficiency Ranges**
  Sufficiency range interpretation offers significant advantages over the use of critical values. First, hidden hunger in the transitional zone can be identified since the beginning of the sufficiency range is clearly above the critical value.

- **Ratios**
  In simplest form, the use of ratios in the interpretation of plant analysis results involves the evaluation of two essential elements together recognizing the effect of one element on the other.
Pengenalan Unit

Nutrients can occur in gaseous form (e.g. N\textsubscript{2}, CO\textsubscript{2}), mineral form (e.g. apatite, the main P-containing mineral), inorganic ionic form (e.g. NH\textsubscript{4}, NO\textsubscript{3}\textsuperscript{−}, SO\textsubscript{4}\textsuperscript{2−}), and organic form (bound into various C-based compounds in living or dead organisms or their products). Nutrients are mostly taken up by plants in the ionic form and by animals in organic forms through consumption of living or dead tissues; microorganisms in general may use nutrients in any mineral or organic form, with sometimes high degrees of specialization at the guild or species level. The inter-conversion between forms is mediated by the ecosystem. Nutrient cycling describes the movement within and between the various biotic or abiotic entities in which nutrients occur in the global environment. These elements can be extracted from their mineral or atmospheric sources or recycled from their organic forms by converting them to the ionic form, enabling uptake to occur and ultimately returning them to the atmosphere or soil. Nutrient cycling is enabled by a great diversity of organisms and leads to creation of a number of physical structures and mechanisms that regulate the fluxes of nutrients among compartments. Nutrient cycling requires a large number of different organisms from diverse functional groups. Ecosystem nutrient balance is the net result of inputs minus outputs. Negative and positive balances are ultimately unsustainable. The magnitude and duration of nutrient imbalance that can be tolerated is determined by an ecosystem’s buffering capacity.

Objektif Unit

1. Comprehend the various biotic or abiotic entities in which nutrients occur in the global environment.
2. Understand the soil processes that affect the availability of essential nutrients to plants
3. Elucidate general approaches to integrated nutrient management in the soil-plant system
1.1 Introduction to nutrient cycle in natural ecosystem
   a) Input of nutrients to ecosystems occurs through five processes

1.2 Carbon, Nitrogen, Phosphorus and Potassium cycles
   a) The Geological Carbon Cycle
   b) The Biological Carbon Cycle
   c) Nitrogen Fixation methods
   d) Mineralization of nitrogen
   e) Nitrification
   f) Denitrification
   g) Phosphorus Cycle
   h) Potassium cycles

1.3 Integrated nutrient system and nutrient balance
   a) Balanced fertilization
   b) Integrated nutrient management (INM)
   c) Management of Crop Residues
   d) Strategies and practices for integrated nutrient management

Isi-isi Penting

1. Nutrient cycling
2. Net Carbon sink
3. Net Carbon source
4. Nitrogen fixation
5. Integrated nutrient management (INM)
6. Balanced fertilization

Pemerhatian/Pandangan/Pendapat
Kesimpulan Unit Tersebut

1. Nutrients exist in several pools. The crop available and exchangeable pools are most critical for meeting short-term crop needs.
2. In most nutrient cycles the basic processes occurring are mineralization, immobilization, sorption, precipitation, weathering and losses.
3. Organic matter is a complex and dynamic soil component that exerts a major influence on soil behavior, properties and functions in the ecosystem.
4. Enormous amount of carbon is stored in soil organic matter and these are an important tool for moderating global greenhouse effect.
5. The carbon-to-nitrogen ration (C/N) of determines mineralization and availability of nutrients in the soil ecosystem.
6. The level of soil organic matter is influenced by climate (being higher in temperate moist regions).
7. The challenges of nutrient management are threefold: 1) to provide adequate nutrients for plants in the system; 2) to simultaneously ensure that inputs are in balance with plant utilization of nutrients; and prevent environmental contamination.

Rujukan Tambahan (jika ada)

Latihan 1 / Aktiviti 1

2. Describe the process that occur as shown in the figure below.
Latihan dalam kumpulan 1 / Perbincangan 1

Each group will do the assigned readings and discuss among the members based on a list of questions, issues, statements given in the activity sheet. Selected questions or issues will be presented in class.
1. Read the Brief Notes on: *Introduction to nutrient cycle in natural ecosystem.*
2. Read pages 311-315 of *Soils in our Environment (11th Ed.)*.
3. Review the power point slides located at the class website
4. Your presentation should focus on the following questions:
   a. How do you describe the concept of nutrient cycling?
   b. What are the processes through which input of nutrients to ecosystems occur?
   c. What are the goals and concerns in soil fertility management?

Latihan dalam kumpulan 2 / Perbincangan 2

Each group will do the assigned readings and discuss among the members based on a list of questions, issues, statements given in the activity sheet. Selected questions or issues will be presented in class.
1. Read the Brief Notes on: *carbon, nitrogen, phosphorus and potassium cycles*
2. Read pages 495-539, 542-574 and 594-636 of *Nature and Properties of Soils (14th Ed.)*.
3. Review the power point slides located at the class website
4. Your presentation should focus on the following questions or issues:
   a) How do you draw the carbon, nitrogen, phosphorus and potassium cycles?
   b) What are the necessary conditions for ammonia volatilization and denitrification losses of Nitrogen?
   c) What are the major pathways in nitrogen cycling and nitrogen loss?
   d) Why are nitrogen fertilizers only 40-70% efficient in the tropics?
   e) What happen to phosphorus fertilizers not used by the plants?
   f) Why is phosphorus more available at pH 6-7 than at pH values of 4 or 8?
   g) What is meant by the term eutrophication and how is it influenced by farm practices involving phosphorus?
Latihan dalam kumpulan 3 / Perbincangan 3

The class will be divided into groups and each group will do the assigned readings and discussion based on a list of questions, issues, statements given in the activity sheet. Selected questions or issues will be presented in class.

1. Read the Brief Notes on: *Integrated nutrient system and nutrient balance.*
3. Review the power point slides located at the class website.
4. Your presentation should focus on the following questions or issues:
   a) What is your understanding of the terms balanced fertilization and integrated nutrient management?
   b) What are the main mechanisms through which nutrients are added and lost through the soil system?
   c) Compare the relative advantages and disadvantages of organic and inorganic nutrient sources.
   d) Discuss the concept of limiting factor and indicate is importance enhancing or constraining plant growth.
   e) Why are nutrient cycling problems in agricultural systems more prominent than those in forested areas?
Jawapan Latihan 1

3. The cycling of nutrients in an ecosystem are interlinked by a number of processes that move atoms from and through organisms and to and from the atmosphere, soil and/or rocks, and water. Nutrients can flow between these compartments along a variety of pathways.

Jawapan Latihan Dalam Kumpulan / Perbincangan

1. **Soalan 4**: See lecture notes
2. **Soalan 4**: See lecture notes
3. **Soalan 4**: See lecture notes
INTRODUCTION TO NUTRIENT CYCLE IN NATURAL ECOSYSTEM

Nutrients can occur in gaseous form (e.g. N<sub>2</sub>, CO<sub>2</sub>), mineral form (e.g. apatite, the main P-containing mineral), inorganic ionic form (e.g. NH<sub>4</sub>, NO<sub>3</sub>, SO<sub>4</sub><sup>2-</sup>), and organic form (bound into various C-based compounds in living or dead organisms or their products). Nutrients are mostly taken up by plants in the ionic form and by animals in organic forms through consumption of living or dead tissues; microorganisms in general may use nutrients in any mineral or organic form, with sometimes high degrees of specialization at the guild or species level. The inter-conversion between forms is mediated by the ecosystem.

Nutrient cycling describes the movement within and between the various biotic or abiotic entities in which nutrients occur in the global environment. These elements can be extracted from their mineral or atmospheric sources or recycled from their organic forms by converting them to the ionic form, enabling uptake to occur and ultimately returning them to the atmosphere or soil. Nutrient cycling is enabled by a great diversity of organisms and leads to creation of a number of physical structures and mechanisms that regulate the fluxes of nutrients among compartments. Nutrient cycling requires a large number of different organisms from diverse functional groups.

Ecosystem nutrient balance is the net result of inputs minus outputs. Negative and positive balances are ultimately unsustainable. The magnitude and duration of nutrient imbalance that can be tolerated is determined by an ecosystem’s buffering capacity.

**Input of nutrients to ecosystems occurs through five processes:**

1. Weathering from geological sources generally produces relatively small quantities of nutrients over long periods of time. The nature and composition of bedrock, in interaction with the climate, largely determines the flux.

2. Atmospheric input of nutrients can occur through wet or dry deposition of elements previously released to the atmosphere by fires (biomass or combustion of fossil fuels), intensive farming practices (such as pig farms or cattle feedlots), and wind erosion.

3. Biological processes include the fixation of atmospheric C (CO<sub>2</sub>) through photosynthesis, and atmospheric N (N<sub>2</sub>) through biological N fixation.
4. Nutrients can be released from the biomass of mobile organisms that enter an ecosystem and suffer mortality. This also occurs through the lateral transfer of nutrients, primarily in water flows.

5. Direct anthropogenic inputs occur through fertilization practices used in intensive agriculture and through the release of human sewage and livestock wastes.

**CARBON CYCLE**

Carbon is the fourth most abundant element in the universe, and is absolutely essential to life on earth. The cycle consists of several storage pools of carbon and the processes by which the various pools exchange carbon. If more carbon enters a pool than leaves it, that pool is considered a net carbon sink. If more carbon leaves a pool than enters it, that pool is considered net carbon source. The global carbon cycle, one of the major biogeochemical cycles, can be divided into geological and biological components. The geological carbon cycle operates on a time scale of millions of years, whereas the biological carbon cycle operates on a time scale of days to thousands of years.

**The Geological Carbon Cycle**

The geological component of the carbon cycle is where it interacts with the rock cycle in the processes of weathering and dissolution, precipitation of minerals, burial and subduction, and volcanism. In the atmosphere, carbonic acid forms by a reaction with atmospheric carbon dioxide (CO_2) and water. As this weakly acidic water reaches the earth as rain, it reacts with minerals at the earth’s surface, slowly dissolving them into their component ions through the process of chemical weathering. These component ions are carried in surface waters like streams and rivers eventually to the ocean, where they precipitate out as minerals like calcite (CaCO_3). Through continued deposition and burial, this calcite sediment forms the rock called limestone.

**The Biological Carbon Cycle**

Biology plays an important role in the movement of carbon between land, ocean, and atmosphere through the processes of photosynthesis and respiration. Plants take in carbon dioxide (CO_2) from the atmosphere during photosynthesis, and release CO_2 back into the atmosphere during respiration through the following chemical reactions:

**Respiration:**
\[ C_6H_{12}O_6 \text{(organic matter)} + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy} \]

**Photosynthesis:**
\[ \text{energy (sunlight)} + 6CO_2 + H_2O \rightarrow C_6H_{12}O_6 + 6O_2 \]
Through photosynthesis, green plants use solar energy to turn atmospheric carbon dioxide into carbohydrates (sugars). Plants and animals use these carbohydrates (and other products derived from them) through a process called respiration, the reverse of photosynthesis. The amount of carbon taken up by photosynthesis and released back to the atmosphere by respiration each year is about 1,000 times greater than the amount of carbon that moves through the geological cycle on an annual basis.

Suffice to say here that the global C cycle is currently out of balance, principally as a result of the burning of fossil fuels, but also due to the conversion of high C-density natural ecosystems, such as forests and grasslands, to lower C-density agro-ecosystems.

**NITROGEN CYCLE**

Nitrogen is the major component of atmosphere comprising 79% percent of it. It is also an essential component of organic molecules such as amino acids, proteins, nucleic acids, vitamins, pigments etc. The nitrogen cycle refers to the sequence of chemical and biological changes undergone by nitrogen as it moves from the atmosphere into water, soil and living organisms and upon death of these organisms (plants and animals) is recycled through a part of all of the entire process.
The greater bulk (90-99%) of the soil nitrogen is in organic compounds that protect it from loss but leave it largely unavailable to higher plants. Much of this nitrogen is present in amine groups (R-NH₂), largely in proteins or as part of humic compounds.

Five main processes of the nitrogen cycle are: nitrogen fixation, nitrogen uptake (organism growth), nitrogen mineralization (decay), nitrification, and denitrification. Microorganisms, particularly bacteria, play major roles in all of the principal nitrogen transformations.

**Nitrogen Fixation methods**

Nitrogen fixation is the process wherein N₂ is converted to ammonium. Nitrogen fixation is achieved through the following ways:

A. **Biological N fixation** processes include:
   - **Symbiotic bacteria:** Certain symbiotic bacteria of genus *Rhizobium* can fix nitrogen when in combination with cells from the roots of legumes like pea, bean and alfalfa. The bacteria invade the roots and stimulate the formation of root nodules - a sort of harmless tumor. In this relationship, nitrogen fixing bacteria inhabit legume root nodules and receive carbohydrates and a favorable environment from their host plant in exchange for some of the nitrogen they fix. Nodule bacteria can fix 50-100 kilograms per acre per year.
   - **Non-symbiotic N fixation:** This is a N₂ fixation process that is performed by free-living bacteria (e.g. *Azotobacter*) and blue-green algae in the soil. The amount of N₂ fixed by these organisms is much lower than that fixed by symbiotic N₂ fixation.
B. Non-biological N fixation processes include:

- **Lightening**: High-energy natural events such as lightning, forest fires, and even hot lava flows can cause the fixation of smaller, but significant amounts of nitrogen. The high energy of these natural phenomena can break the triple bonds of N₂ molecules, resulting in ammonia (NH₃) and nitrates (NO₃⁻). These forms are carried to Earth in precipitation.

- **Synthetic or industrial processes of N Fixation**: The industrial fixation of N is the most important source of N as a plant nutrient. The production of N by industrial processes is based on the Haber-Bosch process where hydrogen (H₂) and N₂ gases react to form NH₃.

**Mineralization of nitrogen**

When soil microbes attack compounds, simple amine compounds are formed. Then the amine groups are hydrolyzed and the nitrogen is released as ammonium ions (NH₄⁺), which can be oxidized to nitrate form. This enzymatic process is called mineralization. Once in the form of ammonium, nitrogen is available for use by plants or for further transformation into nitrate (NO₃⁻) through the process called nitrification. The opposite of mineralization is immobilization. **Immobilization** is the conversion of inorganic nitrogen ions (NO₃⁻ and NH₄⁺) into organic forms.

![Figure 1. Forms of Soil Nitrogen](image)

**Nitrification**

Some of the ammonium produced by decomposition is converted to nitrate via a process called nitrification. The bacteria that carry out this reaction gain energy from it. Nitrification requires the presence of oxygen.

Biochemical processes of nitrification are in two stages:

**Step 1**: \( \text{NH}_4^+ + O_2 \xrightarrow{\text{Nitrosomonas}} \text{NO}_2^- + 2\text{H}^+ + \text{H}_2\text{O} + 275 \text{kJ energy} \)

(Ammonium) \hspace{2cm} \text{(Nitrite)}
**Step 2:** 
\[ \text{NO}_2^- + \text{O}_2 \xrightarrow{\text{Nitrobaeter}} \text{NO}_3^- + 76 \text{ kJ energy} \] 
(Nitrite) \hspace{1cm} (Nitrate)

**Denitrification**

Denitrification is the reduction of nitrates back into nitrogen gas (\(\text{N}_2\)), thus completing the nitrogen cycle. This process is performed by bacterial species such as *Pseudomonas* and *Clostridium* in anaerobic conditions.

\[ \text{NO}_3^- \rightarrow \text{NO}_2^- \rightarrow \text{NO} \rightarrow \text{N}_2\text{O} \rightarrow \text{N}_2 \]  
(Nitrate) \hspace{1cm} (Nitrite) \hspace{1cm} (Nitric oxide) \hspace{1cm} (Nitrous oxide) \hspace{1cm} (Dinitrogen gas)

Nitric oxide and nitrous oxide are both environmentally important gases. Nitric oxide (NO) contributes to smog, and nitrous oxide (\(\text{N}_2\text{O}\)) is an important greenhouse gas, thereby contributing to global climate change.

The lithosphere is the ultimate source of all phosphorus in the Biosphere

**PHOSPHORUS CYCLE**

Phosphorus is a mineral element crucial for normal functioning of the living organisms. Phosphorus is a primary nutrient and plant roots take up P in the forms of \(\text{HPO}_4^{2-}\) and \(\text{H}_2\text{PO}_4^-\). The phosphorus cycle is the biogeochemical cycle that describes the movement of phosphorus through the lithosphere, hydrosphere, and biosphere. Unlike many other biogeochemical cycles, the atmosphere does not play a significant role in the movements of phosphorus, because phosphorus and phosphorus-based compounds are usually solids at the typical ranges of temperature and pressure found on Earth.
The Phosphorus Cycle

Phosphates move quickly through plants and animals; however, the processes that move them through the soil or ocean are very slow, making the phosphorus cycle overall one of the slowest biogeochemical cycles. Phosphorus moves slowly from deposits on land and in sediments, to living organisms, and then much more slowly back into the soil and water sediment.

It is in these rocks where the phosphorus cycle begins. When it rains, phosphates are removed from the rocks (via weathering) and are distributed throughout both soils and water. Plants take up the phosphate ions from the soil. The phosphates then moves from plants to animals when herbivores eat plants and carnivores eat plants or herbivores. The phosphates absorbed by animal tissue through consumption eventually returns to the soil through the excretion of urine and feces, as well as from the final decomposition of plants and animals after death.

Phosphorus is not highly soluble, binding tightly to molecules in soil; therefore it mostly reaches waters by traveling with runoff soil particles. Phosphates also enter waterways through fertilizer runoff, sewage seepage, natural mineral deposits, and wastes from other industrial processes. These phosphates tend to settle on ocean floors and lake bottoms. As sediments are stirred up, phosphates may reenter the phosphorus cycle, but they are more commonly made available to aquatic organisms by being exposed through erosion. Water plants take up the waterborne phosphate which then travels up through successive stages of the aquatic food chain. Phosphorus availability and mobility is influenced by several factors such as pH. In acid soils, P precipitates as relatively insoluble Fe and Al phosphate minerals. In neutral and calcareous soils, P precipitates as relatively insoluble Ca phosphate minerals.
**POTASSIUM CYCLE**

Potassium is the third primary plant nutrient and is absorbed by plants in larger amounts than any other nutrient except N. Plants take up K as the monovalent cation $K^+$. Potassium is present in relatively large quantities in most soils, but only a small percentage of the total soil K is readily available for plant uptake. Potassium exists in the soil as dissolved $K^+$ ions (solution K), exchangeable K, non-exchangeable K, and mineral K.

In the soil, weathering releases K from a number of common minerals including feldspars and micas. The released $K^+$ can be taken up easily by plant roots, adsorbed by the cation exchange complex of clay and organic matter, or “fixed” in the internal structure of certain 2:1 clay minerals. Potassium that is “fixed” by these clay minerals is very slowly available to the plant.

**Potassium availability and mobility**

- **Plant available K**: Although mineral K accounts for 90 to 98% of the total soil K, readily and slowly available K represent only 1 to 10% of the total soil K. Plant available K (K that can be readily absorbed by plant roots) includes the portion of the soil K that is soluble in the soil solution and exchangeable K held on the exchange complex.
- **Exchangeable K** is that portion of soil K which is in equilibrium with K in the soil solution:

\[
\text{Exchangeable K} \leftrightarrow \text{Solution K}
\]

K is continuously made available for plant uptake through the cation exchange process. There can be a continuous, but slow, transfer of K from soil minerals to exchangeable and slowly available forms as K is removed from the soil solution by crop uptake and leaching.

**INTEGRATED NUTRIENT SYSTEM AND NUTRIENT BALANCE**

**Balanced fertilization** refers to the practice of applying the required plant nutrients after taking into account available nutrients in the soil, crop requirement, cropping sequence and crop management practices like weed control, irrigation etc. Long-term security of the global food supply requires a balance between increasing production and environmental sustainability. Both nutrient scarcities and surpluses alike can threaten this balance. Integrated Nutrient Management for Sustainable Crop Production examines the challenges of managing both organic and inorganic nutrient sources in agricultural systems where nutrients are deficient or in excess supply.

To ensure a sufficient nutrient supply for crops, there is need to keep an even nutrient balance in the soil. The loss of nutrients has to be minimized, and the addition of nutrients maximized in order to avoid a depletion of nutrients in the soil.

**Integrated nutrient management (INM)** refers to the practice of integrated use of all natural and man-made resources of plant nutrients so that the crop productivity increases efficiently and environmentally friendly manner without sacrificing the soil productivity of the future generations. Sufficient and balanced application of organic manures and fertilizers is the key component of INM.

**Nutrients can be lost in the following processes:**
- Removal of the harvest (all of the nutrients)
- Volatilization (especially N)
- Run-off (especially N)
- Fixation (especially P)
- Leaching
- Erosion (all nutrients)

**Nutrients are added in the following processes:**
- Decomposition of organic matter (all nutrients)
- Nitrogen fixation (only N)
- Weathering (mostly K and Mg)
- Chemical fertilizer (mostly N, P, and K)
- Rain and solid matter deposits.

Most soils in the tropical region are highly weathered and infertile. A sustainable crop production system must adopt an ecological approach, using balanced nutrient
inputs from inorganic, organic and biological sources. Achieving food security for a rapidly expanding population in the tropics means intensifying food production on existing cropland through enhanced nutrient input and recycling. Sustainable soil nutrient-enhancing strategies involve the wise use and management of inorganic and organic nutrient sources in ecologically sound production systems. The primary goal of integrated nutrient management (INM) is to combine old and new methods of nutrient management into ecologically sound and economically viable farming systems that utilize available organic and inorganic sources of nutrients in a judicious and efficient way. Integrated nutrient management optimizes all aspects of nutrient cycling. It attempts to achieve tight nutrient cycling with synchrony between nutrient demand by the crop and nutrient release in the soil, while minimizing losses through leaching, runoff, volatilization and immobilization.

Management of Crop Residues

Organic nutrient sources include plant residues, leguminous cover crops, mulches, green manure, animal manure, and household wastes. Under continuous cropping, recycling and reusing nutrients from organic sources may not be sufficient to sustain crop yields. Nutrients exported from the soil through harvested biomass or lost from soil by gaseous loss, leaching, or erosion must be replaced with nutrients from external sources.

Physically, it improves soil structure and increases water holding capacity. Chemically, it increases the capacity of the soil to buffer changes in pH, increases the cation retention capacity (CEC), reduces phosphate fixation, and serves as a reservoir of secondary nutrients and micronutrients. Biologically, organic matter is the energy source for soil fauna and microorganisms, which are the primary agents that manipulate the decomposition and release of mineral nutrients in soil ecosystems.

Organic matter in soil exists as partially decomposed plant and animal residues, living and dead microorganisms, and humified organic matter or humus. Stable humus constitutes 50 to 75% of the total soil carbon and is little affected by management. Rates of decomposition of both fresh plant residues and humified soil organic matter are three to five times greater in the humid tropical environment than under temperate conditions.

Strategies and practices for integrated nutrient management include:

1. Composting and addition of Organic Matter:

Organic nutrient sources include plant residues, leguminous cover crops, mulches, green manure, animal manure, and household wastes. Organic matter in soil exists as partially decomposed plant and animal residues, living and dead microorganisms, and humified organic matter or humus.

Advantages of organic matter:

- Physically, it improves soil structure and increases water holding capacity.
- Chemically, it increases the capacity of the soil to buffer changes in pH, increases the cation retention capacity (CEC), reduces phosphate fixation, and serves as a reservoir of secondary nutrients and micronutrients.
• Biologically, organic matter is the energy source for soil fauna and microorganisms, which are the primary agents that manipulate the decomposition and release of mineral nutrients in soil ecosystems.

2. Farm Yard manure:
Farmyard manure such as cattle dung are major sources of nutrients for food crops in many parts of the tropics and reduce the need for fertilizer.

3. Green Manure crops:
Timely applications of organic materials with a low C/N ratio, such as green manure and compost, could synchronize nutrient release with plant demand and minimize the amount of inorganic fertilizer needed to sustain high crop yields.

Advantages of Leguminous green manures and cover crops:
• Enrich the soil with biologically fixed N.
• Conserve and recycle soil mineral nutrients.
• Provide ground cover to minimize soil erosion
• Require little or no cash input.

However, additional labor is required for timely establishment, maintenance and incorporation.

4. Mulching and conservation tillage practices:
The role of mulches and tillage practices in conserving soil moisture, with the subsequent effect on crop yields, has long been recognized.

5. Agroforestry:
Agroforestry refers to all forms of land-use systems in which trees or woody perennials are deliberately planted on the same land management unit in association with livestock and/or annual crops, with significant ecological interactions.

6. Chemical fertilizers and soil amendments:
Judicious use (i.e. lower rates, split application, banding) of inorganic fertilizers is needed on infertile soils, to sustain high crop yields and maintain an optimum balance of nutrients. Liming should also be practiced under acidic conditions.
UNIT 3
FERTILIZER AND FERTILIZATION

Pengenalan Unit

Fertilizer is any material that supplies one or more of the essential nutrients to plants.

Straight Fertilizers: These are products where a nitrogen, phosphate or potassium.

Compound Fertilizer: Fertilizer is having a declared content of at least two of the nutrients, nitrogen, phosphorus and potassium, obtained chemically or by blending, or both.

Complex Fertilizer: Fertilizer having a declared content of at least two of the nutrients nitrogen, phosphorus and potassium, obtained by chemical reaction.

Fertilizers can be classified into one of two categories: organic or inorganic. Organic fertilizers are derived from living or once living material. Inorganic fertilizers are derived from non-living sources and include most of our man-made, commercial fertilizers.

Objektif Unit

4. Distinguish various forms of fertilizers.
5. Perform important fertilizer calculations
6. Understand fertilizer grade and quality
TOPIK

1.1 Organic fertilizer
   a) Advantages and Disadvantages

1.2 Inorganic / chemical fertilizer
   a) Advantages and Disadvantages

1.3 Methods of Fertilizer application
1.4 Fertilizer Quality
1.5 Liquid Fertilizers
1.6 Fertilizer Calculation
1.7 Fertilizer Efficiency
1.8 Organic Waste Management
1.9 Biofertilizer

Isi-isii Penting

1. Fertilizers
2. Fertilizer quality
3. Fertilizer efficiency
4. Complete fertilizers
5. Balanced fertilization

Pemerhatian/Pandangan/Pendapat
Kesimpulan Unit Tersebut

1. A fertilizer is a substance used to supply essential elements.
2. Fertilizers can be finely ground minerals, organic materials or chemicals made by industry.
3. The Haber process fixes nitrogen from the air to make ammonia.
4. Fertilizers come in a number of physical forms that allow many methods of use.
5. The chemical and physical properties of a fertilizer determine its quality.
6. Fertilizer efficiency on many tropical soils is a concern due to losses associated with surface runoff and leaching.
7. Bio-fertilizers contain living microorganisms which, when applied to soil, colonizes the rhizosphere and promotes plant growth.

Rujukan Tambahan (jika ada)

Latihan 1 / Aktiviti 1

Figure 1

3. Carefully observe the picture above (Figure 1)
4. Discuss why is earth worm activity helpful?
5. Which leaves will decompose faster- those buried underground or those on the soil surface?
Latihan dalam kumpulan 1 / Perbincangan 1

Each group will do the assigned readings and discuss among the members based on a list of questions, issues, statements given in the activity sheet. Selected questions or issues will be presented in class.
5. Read the Brief Notes on: *Fertilizer and Fertilization.*
6. Read pages 291-319 on: *Soil Science and Management (2nd Edition).*
7. Review the power point slides located at the class website
8. Your presentation should focus on the following questions:
   d. How do you compare and contrast between organic and inorganic fertilizers?
   e. What factors determine the physical and chemical properties of fertilizers?
   f. How are biofertilizers useful to plant-soil system?

Latihan dalam kumpulan 2 / Perbincangan 2

1. Each group will do the assigned readings and discuss among the members based on a list of questions, issues, statements given in the activity sheet. Selected questions or issues will be presented in class.

Figure 2: Immature Oil palm
h) Describe the soil conservation measures shown in Figure 2?

i) What are the basic agronomic practices involved in oil palm production?

j) In Figure 1 above, what shortcomings can you observe in the production of the immature oil palm?

k) Name the most common pests and diseases that affect the oil palm industry?

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**Jawapan Latihan 1**

1. See lab notes/textbooks

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**Jawapan Latihan Dalam Kumpulan / Perbincangan**

1. **Soalan 4**: Refer to lecture notes
2. **Soalan 1**: Refer to reference materials
Fertilizer is any material that supplies one or more of the essential nutrients to plants.

**Straight Fertilizers:** These are products where a nitrogen, phosphate or potassium.

**Compound Fertilizer:** Fertilizer is having a declared content of at least two of the nutrients, nitrogen, phosphorus and potassium, obtained chemically or by blending, or both.

**Complex Fertilizer:** Fertilizer having a declared content of at least two of the nutrients nitrogen, phosphorus and potassium, obtained by chemical reaction.

Fertilizers can be classified into one of two categories: organic or inorganic. Organic fertilizers are derived from living or once living material. Inorganic fertilizers are derived from non-living sources and include most of our man-made, commercial fertilizers.

**Advantages of Organic Fertilizers**
1. Improve the structure of the soil.
2. Retain soil moisture.
3. Release nitrogen slowly and consistently.
4. Mobilize existing soil nutrients.
5. Do not burn the plants like some chemical fertilizers.
6. Organic fertilizers also breakdown and release nutrients slowly which helps to prevent leaching.

**Disadvantages of Organic Fertilizers**
1. Often Organic fertilizers, especially those that contain animal and plant feces are contaminated with pathogens. Make sure they are properly composted to reduce the risk of pathogens.
2. Organic fertilizers also have lower nutrient content compared to inorganic fertilizers and this means that more material has to be applied in order to get the same nutrient amount from inorganic fertilizers.
3. More labor is needed to compost organic fertilizer, increasing labor costs.
4. They are usually bulky and difficult to apply.

2. Inorganic/chemical fertilizers
Inorganic or Chemical Fertilizers are primarily derived from chemical compounds such as ammonium nitrate, ammonium phosphates and potassium chloride.

Advantages of Inorganic Fertilizers
1. Higher and accurate amount of nutrients.
2. They are cheap, easy to apply and distribute.
3. The addition of inorganic fertilizer gives the plants the basic nutrient required by the plant like the Phosphorous, nitrogen and potassium.
4. They can release nutrients fast.
5. The use of inorganic fertilizers is time and money saving.

Disadvantages of Inorganic Fertilizers
1. Inorganic fertilizers can burn plants and distort the quality of the soil when applied excessively.
2. They can be easily lost through leaching and surface runoff, which can cause environmental pollution.

Methods of Fertilizer application
Generally 3 methods of application of fertilizers are in practice:

1. Broadcasting: Uniform distribution over the whole cropped field.
2. Placement: Application in bands or in pockets near the plants or plant rows.
3. Foliar application: Using low or high volume sprayers, the fertilizers are sprayed covering the plants.
4. Fertigation: Applying fertilizer through irrigation water.

Fertilizer Quality
The quality of a fertilizer is determined by its elemental ratio or grade. Fertilizer grade refers to the minimum amounts of N, P$_2$O$_5$ and K$_2$O in the fertilizer. A 10-10-10 fertilizer would contain 10 percent nitrogen (N), 10 percent P$_2$O$_5$ equivalent and 10 percent K$_2$O equivalent.
<table>
<thead>
<tr>
<th>Fertilizer</th>
<th>N</th>
<th>P₂O₅</th>
<th>K₂O</th>
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</thead>
<tbody>
<tr>
<td><strong>Nitrogen Fertilizers</strong></td>
<td></td>
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</tr>
<tr>
<td>1. Ammonium sulphate (NH₄)₂ SO₄</td>
<td>21</td>
<td></td>
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<tr>
<td>2. Calcium nitrate Ca(NO₃)₂</td>
<td>16</td>
<td></td>
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<tr>
<td>3. Ammonium nitrate NH₄NO₃</td>
<td>35</td>
<td></td>
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<tr>
<td>4. Calcium ammonium nitrate NH₄NO₃ + CaCO₃</td>
<td>27</td>
<td></td>
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<tr>
<td>5. Urea CO(NH₂)₂</td>
<td>46</td>
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<tr>
<td><strong>Phosphate Fertilizers</strong></td>
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<tr>
<td>6. Single superphosphate (SSP), CaH₄(PO₄)₂⁺ CaHPO₄⁻ 2H₂O</td>
<td>16-18</td>
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<tr>
<td>7. Triple superphosphate (TSP), Ca(H₂PO₄)₂⁺ CaHPO₄</td>
<td>46</td>
<td></td>
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<tr>
<td>8. Phosphate rock (PR), finely ground (&lt; 0.16 mm)</td>
<td>22-40</td>
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<tr>
<td>9. Diammonium phosphate (DAP)</td>
<td>18</td>
<td>46</td>
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<tr>
<td><strong>Potassium Fertilizers</strong></td>
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<tr>
<td>10. Potassium chloride (MOP), KCl</td>
<td>60</td>
<td></td>
<td></td>
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<tr>
<td>11. Potassium sulphate (SOP), K₂SO₄</td>
<td>50</td>
<td></td>
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<tr>
<td>12. Potassium nitrate, KNO₃</td>
<td>13</td>
<td>44</td>
<td></td>
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<tr>
<td><strong>Compound Fertilizers (examples)</strong></td>
<td>15</td>
<td>15</td>
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<td>13. NPK</td>
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<td>14. NPK</td>
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<tr>
<td>15. NPK</td>
<td>22</td>
<td>22</td>
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</tbody>
</table>

The physical and chemical characteristics of fertilizers are important in determining their quality.

**A) Physical Properties of Fertilizers**

Physical properties of fertilizer determine how easily and uniformly the fertilizer spreads during application. Fertilizers with poor physical properties form lumps or dust, flow badly, accumulate too much water or become segregated. The following factors related to physical properties of fertilizers:

1. Particle Size
2. Density
3. Granule Hardness
4. Moisture Content
B) Chemical Properties of Fertilizers
Chemicals used in fertilizer materials work to supplement or replace minerals and nutrients missing from the soil. Chemical properties of fertilizers entail:
1. Nutrient Properties
2. Acidic Properties
3. Nutrient Availability

Liquid Fertilizers
The important physical properties of fluid fertilizers are density, viscosity and pH. The strength of the gelling agent is also important.

Fertilizer Calculation

Two Basic Types of Calculations (nutrient vs. fertilizer)

- You have a given amount of fertilizer and you need to calculate how much nutrient is in it.
- You have a given amount of a nutrient to apply and you need to calculate how much fertilizer to use.

Example of Fertilizer calculations:
1. How many kg of N are in a 50 kg bag of ammonium nitrate (35-0-0)?
   
   Amount of N in 50 kg NH₄NO₃ = 35/100 x 50 kg 
   = 17.5 kg N

2. How many kg of N are in a 150 kg bag of Urea, CO(NH₂)₂?

   Amount of N in 150 kg CO(NH₂)₂ = 46/100 x 150 kg 
   = 69.0 kg N

3. How many kg of NPK (15-15-15) do you need to give you 5 kg of N?

   15 kg N = 100 kg NPK 
   5 kg N = X kg NPK 
   X kg NPK = (5 kg N) x (100 kg NPK)/(15 kg N) 
   Amount of NPK = 33.3 kg

Fertilizer Efficiency

The term efficiency is defined by Barber (1976) as "the amount of increase in yield of the harvested portion of the crop per unit of fertilizer nutrient applied where high yields are obtained." Efficient fertilizer use on many tropical soils apparently still presents severe and unresolved problems. Compared to temperate regions recovery of fertilizer nutrients by crops in tropical soils is lower.
Factors affecting Fertilizer Efficiency

Fertilizer efficiency in the tropics is affected by:

a) Soil factors
b) Efficiency of crops
c) Climatic factors e.g rainfall
d) Nature of fertilizer materials
e) Methods of fertilizer application
f) Fertilizer efficiency modifiers - amendments.

Tips for Efficient use of Fertilizers

1. Select the most fertilizer responsive and best-suited crops and their varieties for the locality.
2. Balanced fertilization should be practiced based on soil test. Fertilizer recommendations should be based on the crop sequence and not on individual crop basis.
3. While all of phosphate and potash are applied as basal dressing, nitrogen should be applied in split doses.
4. Urea can be cured with soil for top dressing to reduce nitrogen losses by thoroughly mixing 1 part of urea with 5 to 10 parts of moist soil and keeping it for 24 hours.
5. Phosphate should be placed 4 to 6 cm below and 4 to 6 cm away from the seeds to ensure maximum availability.
6. Top dressing nitrogen and potassic fertilizers should be mixed properly with the layer of soil.
7. In dry soil, fertilizers should be placed only in the moist zone.
8. Weeds if not effectively controlled during the first 40 days of crop growth, take away about 30 to 40% of plant nutrients applied to the crops. Therefore, it is necessary to control the weeds particularly during the early stage of crop growth.
9. Sowing of crop should be done at the normal time suited for the locality to get the benefit of maximum efficiency of applied fertilizers.
10. Optimum plant population of the crop needs to be maintained by adopting proper plant spacing.
11. Timely control of pests and diseases will help in realizing maximum effectiveness from fertilizers.

Organic Waste Management

Many organic wastes contain nutrients and organic matter that can benefit plant growth and soil productivity. Recycling these materials onto land captures nutrients that would otherwise be lost, and helps sustain resource base. Organic wastes are utilized in agriculture mainly for improving the soil physical and chemical properties and for nutrient sources for growing crops.

Organic wastes include animal manures, crop residues, and food processing wastes, municipal biosolids and wastes from some industries. Organic wastes are typically by-products of farming, industrial or municipal activities, and are usually called
“wastes” because they are not the primary product. Possible uses of organic wastes include use as fertilizer and soil amendment, energy recovery (heat, liquid fuels, electricity), and production of chemicals (volatile organic acids, ammonium products, alcohols).

**Soil Organic Matter**

Soil organic matter is that fraction of the soil composed of plant and animal remains in various stages of decomposition, cells and tissues of soil organisms, and substances from plant roots and soil microbes. Well decomposed organic matter forms humus, a dark brown, porous, spongy material that has a pleasant, earthy smell. In most soils, the organic matter accounts for less than about 5% of the volume.

- Components of soil organic matter are: soil, water, air and living organisms
- Soil organisms continually change organic compounds from one form to another. They consume plant residue and other organic matter, and then create by-products, wastes, and cell tissue.
- SOM (Soil organic matter) increases the nutrient holding capacity of soil (CEC).
- SOM improves water infiltration, decreases evaporation and increases water holding capacity, especially in sandy soils.
- SOM is generally used to represent the organic constituents in the soil, including undecayed plant and animal tissues, their partial decomposition products, and the soil biomass.
- SOM is frequently said to consist of humic substances and non-humic substances.
- Non-humic substances are all those materials that can be placed in one of the categories of discrete compounds such as sugars, amino acids, fats and so on.
- Humic substances are series of relatively high-molecular-weight, brown to black colored substances formed by secondary synthesis reactions.

**Biofertilizer**

Biofertilizer is a substance which contains living microorganisms which, when applied to soil, colonizes the rhizosphere and promotes growth by increasing the supply or availability of primary nutrients to plants.

The soil microorganisms used in biofertilizers are: Phosphate Solubilizing microbes, Mycorrhizae, Azospirillum, Azotobacter, Rhizobium, Sesbania, Blue Green Algae, and Azolla.
Types of biofertilizers

1. For Nitrogen
   • Rhizobium for legume crops.
   • Azotobacter/Azospirillum for non legume crops.
   • Acetobacter for sugarcane only.
   • Blue –Green Algae (BGA) and Azolla for low land paddy.

2. For Phosphorous
   • Phosphatika for all crops to be applied with Rhizobium, Azotobacter, Azospirillum and Acetobacter.

3. For enriched compost.
   • Cellulolytic fungal culture.
   • Phosphotika and Azotobacter culture.

Benefits of using Biofertilizers

• Increase availability or uptake of nutrients through solubilization or increased absorption.
• Stimulate plant growth through hormonal or antibiotics action or by decomposing organic waste.
• Increase crop yield by 20-30%.
• They are cheap, hence, reduced cost of cultivation.
• Improves soil properties and sustaining soil fertility.
• Lead to soil enrichment.
• Are compatible with long term sustainability.
• Build up soil fertility in the long term.
• Curtails the requirement of inputs.
• They are eco-friendly and pose no damage to the environment.

Disadvantages of biofertilizers

• Specific to the plants.
• Rhizobium spp. culture doesn't work well in high nitrate tolerant strains of soybean.
• The acceptability of biofertilizers has been rather low chiefly because they do not produce quick and spectacular responses.
• Require skill in production and application.
• Difficult to store
UNIT 4
SOIL WATER

Pengenalan Unit

The variable amount of water contained in a unit mass or volume of soil and the energy state of water in the soil are important factors affecting the growth of plants.

Objektif Unit

7. Classify the types of soil water
8. Understand and assess soil water quality
9. Understand water conservation efforts in plant production

TOPIK

1.10 Soil water
    a) Saturated and Unsaturated Flows
    b) Hydraulic Conductivity and Infiltration
    c) Measuring soil moisture
    d) Forms of Soil Water

1.11 Water quality
    a) Inherent and Dynamic Qualities of Soil
    b) Assessing Soil Quality

1.12 Water conservation
    a) Methods of Water Conservation
Isi-isı Penting

1. Field capacity
2. Saturated flow
3. Unsaturated flow
4. Gravitational water
5. Hydraulic conductivity
6. Capillary water
7. Infiltration

Pemerhatian/Pandangan/Pendapat

Kesimpulan Unit Tersebut

1. Water is stored in pores and inorganic and on organic and inorganic surfaces in pedons.
2. The pore size distribution, the amount of surface area and the amount of water in the pedon contributes to the rate of water movement.
3. Water flow in soils may occur in both unsaturated and saturated conditions.
4. Saturated flow occurs when soil pores are completely filled with water.
5. Improving soil infiltration rate by means of preserving soil structure, mulches, and conservation tillage helps to conserve soil water.
6. Hydraulic conductivity of a soil is a measure of the soil's ability to transmit water when submitted to a hydraulic gradient.
7. Water flows from higher potential to lower potential.
Rujukan Tambahan (jika ada)


Latihan 1 / Aktiviti 1

1. Explain the measurement of infiltration of water into the soil using double ring infiltrometer.
Latihan dalam kumpulan 1 / Perbincangan 1

Each group will do the assigned readings and discuss among the members based on a list of questions, issues, statements given in the activity sheet. Selected questions or issues will be presented in class.

1. Read the Brief Notes on: *Soil water.*
2. Read pages 74-98 on *Soil Science and Management (2nd Edition).*
3. Review the power point slides located at the class website
4. Your presentation should focus on the following questions:
   
   a) How do you define key terms related to soil water? E.g saturated and unsaturated flows, hydraulic conductivity and infiltration.
   b) What factors affect movement of water in the soil?

Latihan dalam kumpulan 2 / Perbincangan 2

Each group will do the assigned readings and discuss among the members based on a list of questions, issues, statements given in the activity sheet. Selected questions or issues will be presented in class.

1. Read the Brief Notes on: *Water quality.*
2. Read pages 91-98 of *Soil Science and Management (2nd Edition).*
3. Review the power point slides located at the class website
4. Your presentation should focus on the following questions or issues:
   
   a) Describe how to measure gravimetric water content in soil?
   b) Describe how to measure volumetric metric water content in soil?
   c) Describe the use of tensiometers in suction measurement.
Latihan dalam kumpulan 3 / Perbincangan 3

The class will be divided into groups and each group will do the assigned readings and discussion based on a list of questions, issues, statements given in the activity sheet. Selected questions or issues will be presented in class.

1. Read the Brief Notes on: Water Conservation.
3. Review the power point slides located at the class website.
4. Your presentation should focus on the following questions or issues:
   a) State the reasons for conserving water.
   b) What are the functions of buffer strips?
   c) How can you treat soil pans?
   d) How conservation tillage does contribute to water conservation?

Jawapan Latihan 1

1. Refer to lab manual and textbook

Jawapan Latihan Dalam Kumpulan / Perbincangan

1. Soalan 4: Refer to lecture notes and textbooks
2. Soalan 2: Refer to lecture notes and textbooks
3. Soalan 3: Refer to lecture notes and textbooks
The variable amount of water contained in a unit mass or volume of soil and the energy state of water in the soil are important factors affecting the growth of plants.

Saturated and Unsaturated Flows

Water flow in soils may occur in both unsaturated and saturated conditions. When soil is saturated with water, i.e. even the macropores are full of water. Water moves in the soil according to the difference in potential (water flows from a higher potential to the state of lower potential, i.e. drier soil). This potential difference is called the hydraulic conductivity of soil. The flow rate of water depends on gradients in soil water potential ($\Psi_m$) caused by differences in height, pressure, dissolved solutes and soil wetness.

Saturated Flow
Saturated flow occurs when soil pores are completely filled with water. Saturated flow in soil with large continuous pores can be rapid if driven by large differences in gravity and pressure. Saturated flow conditions occur in aquifers (water-bearing sediments and rock layers), in flooded soil and in lower horizons of soil with limited drainage.

Unsaturated Flow

The pore space is only partly filled with water, resulting in a soil water pressure smaller than atmospheric pressure. Unsaturated flow is generally rapid through fine sand or well aggregated loams (medium sized pores) and slower through very fine and poorly aggregated clayey soil (very small pores).
Hydraulic Conductivity and Infiltration

**Hydraulic conductivity** of a soil is a measure of the soil's ability to transmit water when submitted to a hydraulic gradient. Hydraulic conductivity, symbolically represented as $K$, is a property of soil that describes the ease with which water can move through pore spaces depends on the intrinsic permeability of the soil and on the degree of saturation. Saturated hydraulic conductivity, $K_{sat}$, describes water movement through saturated media.

**Infiltration rate** in soil science is a measure of the rate at which soil is able to absorb rainfall or irrigation. It is measured millimeters per hour. The rate decreases as the soil becomes saturated. If the precipitation rate exceeds the infiltration rate, runoff will usually occur unless there is some physical barrier. It is related to the saturated hydraulic conductivity of the near-surface soil. The rate of infiltration can be measured using an infiltrometer.

One of the main functions of soil is to store moisture and supply it to plants between rainfalls or irrigations. If the water content becomes too low, plants become stressed. Soil water content is expressed on a gravimetric or volumetric basis.

**Gravimetric water content** ($\theta_g$) is the mass of water per mass of dry soil. It is measured by weighing a soil sample ($m_{wet}$), drying the sample to remove the water, and then weighing the dried soil ($m_{dry}$).

$$\theta_g = \frac{m_{water}}{m_{soil}} = \frac{m_{wet} - m_{dry}}{m_{dry}}$$

**Volumetric water content** ($\theta_v$) is the volume of liquid water per volume of soil. Volume is the ratio of mass to density ($\rho$) which gives:

$$\theta_v = \frac{\text{volume}_{water}}{\text{volume}_{soil}} = \frac{m_{water}}{\rho_{soil}} = \frac{\theta_g \cdot \rho_{soil}}{\rho_{water}}$$
Measuring soil moisture

1. **Gravimetric Method**
   Take a moist sample, weigh, oven dry, weigh and determine % moisture.

2. **Tensiometers**
   Measures soil moisture tensions. It measures the suction that the soil is exerting on the water

3. **Electrical Resistance Method**
   Two electrodes are imbedded in a block of gypsum. When placed in moist soil, the gypsum block becomes moist. A meter is used to measure electrical resistance between the electrodes. The greater the moisture, the greater the flow of current. The meter is calibrated to estimate soil moisture.

Forms of Soil Water

**Chemical water** is an integral part of the molecular structure of soil minerals. It can be held tightly by electrostatic forces to the surfaces of clay crystals and other minerals and is unavailable to plants.

**Gravitational water** is held in large soil pores and rapidly drains out under the action of gravity within a day or so after rain. Plants can only make use of gravitational water for a few days after rain.

**Capillary water** is held in pores that are small enough to hold water against gravity, but not so tightly that roots cannot absorb it. This water occurs as a film around soil particles and in the pores between them and is the main source of plant moisture. This capillary water can move in all directions in response to suction and can move upwards through soil for up to two metres, the particles and pores of the soil acting like a wick.

When soil is saturated, all the pores are full of water, but after a day, all gravitational water drains out, leaving the soil at **field capacity**. Plants then draw water out of the capillary pores, readily at first and then with greater difficulty, until no more can be withdrawn and the only water left are in the micro-pores. The soil is then at **wilting point** and without water additions, plants may die.
Water holding capacity (mm/cm depth of soil) of main texture groups. Figures are averages and vary with structure and organic matter differences.

<table>
<thead>
<tr>
<th>Texture</th>
<th>Field Capacity</th>
<th>Wilting point</th>
<th>Available water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse sand</td>
<td>0.6</td>
<td>0.2</td>
<td>0.4</td>
</tr>
<tr>
<td>Fine sand</td>
<td>1.0</td>
<td>0.4</td>
<td>0.6</td>
</tr>
<tr>
<td>Loamy sand</td>
<td>1.4</td>
<td>0.6</td>
<td>0.8</td>
</tr>
<tr>
<td>Sandy loam</td>
<td>2.0</td>
<td>0.8</td>
<td>1.2</td>
</tr>
<tr>
<td>Light sandy clay loam</td>
<td>2.3</td>
<td>1.0</td>
<td>1.3</td>
</tr>
<tr>
<td>Loam</td>
<td>2.7</td>
<td>1.2</td>
<td>1.5</td>
</tr>
<tr>
<td>Sandy clay loam</td>
<td>2.8</td>
<td>1.3</td>
<td>1.5</td>
</tr>
<tr>
<td>Clay loam</td>
<td>3.2</td>
<td>1.4</td>
<td>1.8</td>
</tr>
<tr>
<td>Clay</td>
<td>4.0</td>
<td>2.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Self-mulching clay</td>
<td>4.5</td>
<td>2.5</td>
<td>2.0</td>
</tr>
</tbody>
</table>

**Source:** Department of Agriculture Bulletin 462, 1960
**Water quality**

Soil quality the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation. The most important issues related to water quality involve salinization and contamination of ground and surface waters by pesticides, nitrates and selenium.

**Inherent and Dynamic Qualities of Soil**

Soil has both inherent and dynamic qualities.

**Inherent soil quality** is a soil’s natural ability to function. For example, sandy soil drains faster than clayey soil. Deep soil has more room for roots than soils with bedrock near the surface. These characteristics do not change easily.

**Dynamic soil quality** is how soil changes depending on how it is managed. Management choices affect the amount of soil organic matter, soil structure, soil depth, water and nutrient holding capacity.

**Assessing Soil Quality**

Soil quality assessment is the process of measuring the management induced changes in soil as we attempt to get soil to do what we want it to do. The ultimate purpose of assessing soil quality is to provide the information necessary to protect and improve long-term agricultural productivity, water quality, and habitats of all organisms including people.

Soil quality cannot be measured directly, so we evaluate indicators. Indicators are measurable properties of soil or plants that provide clues about how well the soil can function. Indicators can be physical, chemical, and biological properties, processes, or characteristics of soils. They can also be morphological or visual features of plants. Useful indicators:

Indicators can be assessed by qualitative or quantitative techniques. After measurements are collected, they can be evaluated by looking for patterns and comparing results to measurements taken at a different time or field.
Examples of soil quality indicators:

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Relationship to Soil Health</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil organic matter (SOM)</td>
<td>Soil fertility, structure, stability, nutrient retention; soil erosion</td>
</tr>
<tr>
<td>Physical: soil structure, depth of soil, infiltration and bulk density; water holding capacity</td>
<td>Retention and transport of water and nutrients; habitat for microbes; estimate of crop productivity potential; compaction, plow pan, water movement; porosity; workability</td>
</tr>
<tr>
<td>Chemical: pH; electrical conductivity; extractable N-P-K</td>
<td>Biological and chemical activity thresholds; plant and microbial activity thresholds; plant available nutrients and potential for N and P loss</td>
</tr>
<tr>
<td>Biological: microbial biomass C and N; potentially mineralizable N; soil respiration.</td>
<td>Microbial catalytic potential and repository for C and N; soil productivity and N supplying potential; microbial activity measure</td>
</tr>
</tbody>
</table>

**Water conservation**

Water conservation can be defined in any of the following ways:

1. Any beneficial reduction in water loss, use or waste as well as the preservation of water quality.
2. A reduction in water use accomplished by implementation of water conservation or water efficiency measures; or,
3. Improved water management practices that reduce or enhance the beneficial use of water.

A successful water management program will use the following simple principles:

**First Principle** – Conserve water whenever possible

**Second Principle** – Reuse water whenever possible

**Third Principle** – Know where and how water is used

**Fourth Principle** – Continually evaluate water use requirements

**Methods of Water Conservation**

1. **Conservation Tillage**
   Conservation tillage helps preserve soil moisture by leaving at least 30% of the soil surface covered with crop stubble, thereby decreasing wind and water erosion. The crop stubble layer reduces evaporation in the soil profile by one-half compared to
bare soil. Conservation tillage can also reduce pollution caused by runoff and enrich 
the soil with organic matter.

2. **Mulch Tillage**
Mulch tillage also called mulch farming is the practice of tilling a soil in a manner that 
most crop residues on the soil surface. The goal of mulch tillage is to control weeds 
and prepare a seedbed for the next crop, yet retain adequate residues on the 
surface to control erosion and improve water conservation.

3. **Contour Tillage**
Contour tillage involves performing cultural operations such as plowing, planting and 
cultivating across the slope of the land so that elevations along rows are almost 
level. This system protects both the soil and water from losses associated with 
runoff.

4. **Furrow Diking**
Furrow diking conserves water by capturing precipitation or irrigation water in small 
earthen dams in the furrows. Water held between the dams can slowly infiltrate into 
the soil, increasing soil moisture and reducing or eliminating runoff. Furrow dikes can 
benefit dry land farmers, sprinkler irrigators and furrow irrigators who water alternate 
rows.

5. **Drip Irrigation**
Drip irrigation applies small amounts of water frequently to the soil area surrounding 
plant roots through flexible tubing with built in or attached emitters. Subsurface drip 
irrigation (SDI) delivers water underground directly to roots. Since water is applied 
directly to individual plant roots, SDI minimizes or eliminates evaporation, provides a 
uniform application of water to all crop plants, and applies chemicals more efficiently. 
Drip irrigation also reduces plant stress and increases crop yield. A carefully 
managed amount of water is applied, thereby avoiding deep percolation and runoff, 
while reducing salt accumulation.

6. **Cover Cropping**
Cover crops are close-growing crops such as legumes or grasses that are grown 
primarily to provide seasonal protection against erosion and for soil improvement. 
They usually main good soil moisture content.

7. **Land Leveling/Level Terraces**
Level bench terraces are widely used on steep slopes where land for crop 
production is limited and where precipitation is high. On steep slopes, bench 
terraces separate the slope into a series of steps, with horizontal or nearly 
horizontal ledges separated from each other by vertical walls. Level bench 
terraces have been used as a water conservation practice.

8. **Other Water Conservation Practices**
- Recycling used water
- Rain Water Harvesting
UNIT 5
IRRIGATION AND DRAINAGE

Pengenalan Unit

The primary goal of drainage, irrigation and soil conservation systems is to contribute, together with effective agricultural technologies, towards high agricultural production.

Objektif Unit

10. Define and explain the importance and methods of drainage
11. Identify methods of irrigation and primary factors affecting water quality for irrigation

TOPIK

1.13 Drainage
   a) Flooded soil
   b) Methods of drainage

1.14 Irrigation system
Isi-isi Penting

1. Surface drainage
2. Subsurface drainage
3. Furrow irrigation
4. Sprinkler irrigation
5. Drip irrigation
6. Localized irrigation

Pemerhatian/Pandangan/Pendapat

Kesimpulan Unit Tersebut

1. Irrigation is an age-old art – as old as civilization.
2. Irrigation is the application of water to soil for the purpose of supplying the moisture essential for normal plant growth and development.
3. The objective of irrigation is to increase crop production on sustainable basis where water is a limitation.
4. Surface irrigation method refers to the manner or plan of water application by gravity flow to the cultivated land wetting either the entire field (uncontrolled flooding) or part of the field (furrows, basins, border strips).
5. Sub-irrigation is the method of applying water beneath the soil surface.
6. Sprinkler irrigation is a method of applying irrigation water which is similar to natural rainfall. Water is conveyed under desired pressure developed by a pump through a network of pipes.
7. Drip irrigation is defined as the precise, slow and frequent application of small quantities of water to the soil in the form of discrete drops, continuous drops, and tiny streams through emitters located at selected points along a water delivery lateral line. It differs from sprinkler irrigation by the fact that only part of the soil surface is wetted.
8. Water Saving due to increased beneficial use of available water and higher water application efficiency.
9. Irrigation efficiencies are the indices which indicate how best the water applied to the farm is being utilized.
10. All irrigation waters are not pure and may contain some soluble salts.
11. Agricultural drainage is the artificial removal and safe disposal of excess water either from the land surface or soil profile, more specifically, the removal and safe disposal of excess gravitational water from the crop root zone to create favorable conditions for crop growth to enhance agricultural production.
12. Broadly drainage systems are of two types—Surface and Sub-surface.

Rujukan Tambahan (jika ada)


Latihan 1 / Aktiviti 1

1. Describe the irrigation and drainage system used in your agricultural locality
Latihan dalam kumpulan 1 / Perbincangan 1

Each group will do the assigned readings and discuss among the members based on a list of questions, issues, statements given in the activity sheet. Selected questions or issues will be presented in class.
5. Read the Brief Notes on: Irrigation and Drainage.
6. Read pages 407-436 on Soils in our Environment (11th Ed.).
7. Review the power point slides located at the class website
8. Your presentation should focus on the following questions:
    a) What is an aquifer?
    b) What are the advantages and disadvantages of ground water compared with surface water as sources of irrigation water?
    c) Describe some current trends in irrigation water use.
    d) Describe suitable methods for determining pH, EC and nutrients concentration in irrigation water for the purpose of water quality tests.

Latihan dalam kumpulan 2 / Perbincangan 2

Each group will do the assigned readings and discuss among the members based on a list of questions, issues, statements given in the activity sheet. Selected questions or issues will be presented in class.
5. Read the Brief Notes on: Water quality.
6. Read pages 437-456 on Soils in our Environment (11th Ed.).
7. Review the power point slides located at the class website
8. Your presentation should focus on the following questions or issues:
    d) Describe the changes in aeration and pH as paddies are flooded.
    e) What advantages do plastic tube drains have compared to other drainage systems?
Jawapan Latihan 1

1. Refer to internet/reference materials

Jawapan Latihan Dalam Kumpulan / Perbincangan

1. **Soalan 4:** Refer to lecture notes
2. **Soalan 4:** Refer to lecture notes
The primary goal of drainage, irrigation and soil conservation systems is to contribute, together with effective agricultural technologies, towards high agricultural production.

**Drainage**

Drainage is the removal of excess water from soil. Improper drainage can lead to poor soil quality and subsurface seepage which could be harmful to the soil environment.

**Importance of Drainage**

The purpose of agricultural drainage is to remove excess water from the soil in order to enhance crop production. In some soils, the natural drainage processes are sufficient for growth and production of agricultural crops, but in many other soils, artificial drainage is needed for efficient agricultural production.

Improving drainage on agricultural land not only enhances crop production but also has a role in soil conservation. Agricultural drainage improvement can help reduce year-to-year variability in crop yield, which helps reduce the risks associated with crop production. Improved field access through enhanced drainage also extends the crop production season and reduces damage to equipment and soil that can occur under wet conditions. Maintaining existing agricultural improvements and improving the drainage on wet agricultural soils presently in agricultural production helps minimize the need for producers to convert additional land to agricultural production.

Drainage is important to avoid excess water stress to the crop. Excess water has been shown to decrease yields of certain crops such as wheat, oats and barley. Other benefits of drainage include: maintaining soil temperature for optimum plant growth, increased soil air in root zone, increased availability of nutrients, and reduced risk of delayed harvesting, less damage to equipment, less overlapping of inputs during field operations and more effective weed control.

Historically, the main reason for drainage on agricultural land has been to enhance crop production. Drainage removes excess water from the soil and helps to create a well-aerated root environment that enhances plant uptake of nutrients. Drainage on wet agricultural soils allows timely field operations, and helps plant growth to begin early, continue vigorously, and achieve improved levels of productivity. In areas that depend heavily on irrigation from surface water supplies, subsurface drainage is
often used to prevent harmful buildup of salt in the soil. Drainage benefits crop production by minimizing risks, improving efficiency, and increasing net income.

**Flooded Soil**

Flooded soils occur with complete water saturation of soil pores, and generally result in anoxic conditions of the soil environment. Flooded soil environments may include such ecosystem as: rice paddies; wetlands (swamps, marshes, and bogs); compacted soils; and post-rain soils. Additionally, similar redox conditions (where oxygen is lacking) can also be found within soil aggregates and along pollutant plumes, and thus many of the concepts discussed in this section may be applied to those environments.

Due to their low mineralization rate under reduced conditions, flooded soils tend to accumulate high organic carbon contents. These high organic matter contents have strong influence on soil structural behavior.

When a soil is flooded (anaerobic conditions), microorganisms use the available soil O$_2$ to survive. Free O$_2$ in the soil is usually depleted within a couple of days after flooding. The longer the soil is flooded, the lower the soil O$_2$ levels become (more reduced). The deeper the flood, the less O$_2$ can move from the air into the soil. Most upland crops cannot tolerate prolonged saturation or flooding. In contrast, rice has the ability to transport O$_2$ from the leaves and stems to the roots.

**Effects of Flooding**

In waterlogged soil, diffusion of gases through soil pores is so strongly inhibited by their water content that it fails to match the needs of growing roots. A slowing of oxygen influx is the principal cause of injury to roots, and the shoots they support (Vartapetian and Jackson, 1997). The maximum amount of oxygen dissolved in the floodwater in equilibrium with the air is a little over 3 % of that in a similar volume of air itself. This small amount is quickly consumed during the early stages of flooding by aerobic micro-organisms and roots (Figure 1).

In addition to imposing oxygen shortage, flooding also impedes the diffusive escape and/or oxidative breakdown of gases such as ethylene (Arshad and Frankenberger, 1990) or carbon dioxide that are produced by roots and soil micro-organisms. This leads to accumulations that can influence root growth and function. For example, accumulated ethylene may slow root extension, while carbon dioxide in the soil can severely damage roots of certain species.
Figure 1. Effect of flooding on (i) the displacement and exclusion of aerial oxygen from the soil, entrapment of metabolically generated gases in the soil and (ii) the consequences, over time, of bacterial respiration for soil redox potential, loss of free nitrate and subsequent generation of chemically reduced end-products.

Methods of Drainage
Agricultural drainage improvements can be made on the soil surface, the subsurface, or a combination of both.

1. Surface Drainage
Surface drainage is designed to remove standing water from the soil surface. The purpose of using surface drainage is to minimize crop damage from water ponding after a precipitation event, and to control runoff without causing erosion.

It affects the water table by reducing the volume of water entering the soil profile. This type of drainage includes land leveling and smoothing; the construction of surface water inlets to subsurface drains; and the construction of shallow ditches and grass waterways, which empty into open ditches and streams.

Many fields have low spots or depressions where water ponds. Surface drainage techniques such as land leveling, constructing surface inlets to subsurface drains, and the construction of shallow ditches or waterways can allow the water to leave the field rather than causing prolonged wet areas.

2. Subsurface Drainage
Subsurface drainage is designed to remove excess water from the soil profile. The water table level is controlled through a series of drainage pipes (tile or tubing) that are installed below the soil surface, usually just below the root zone. Subsurface drainage pipes are typically installed at a depth of 30 to 40 inches, and at a spacing of 20 to 80 feet. The subsurface drainage network generally outlets to an open ditch or stream.
Irrigation

Irrigation is the application of water to the soil to supplement natural precipitation and provide an environment that is optimum for crop production.

Objectives of Irrigation
- To Supply Water Partially or Totally for Crop Need
- To Cool both the Soil and the Plant
- To Leach Excess Salts
- To improve Groundwater storage
- To Facilitate continuous cropping
- To Enhance Fertilizer Application - Fertigation

Irrigation System

1. **Sprinkler Irrigation**
   Sprinkler irrigation is where water is sprayed from overhead. This system is more tolerant of variable soil textures since the rate of application can be more adequately controlled.

2. **Drip Irrigation**
   While drip irrigation may be the most expensive method of irrigation, it is also the most advanced and efficient method in respect to effective water use. Usually used to irrigate fruits and vegetables, this system consists of perforated pipes that are placed by rows of crops or buried along their root lines and emit water directly onto the crops that need it. As a result, evaporation is drastically reduced and 25% irrigation water is conserved in comparison to flood irrigation.
3. **Flood and Furrow Irrigation**

In flood irrigation, a large amount of water is brought to the field and flows on the ground among the crops. In regions where water is abundant, flood irrigation is the cheapest method of irrigation and this low tech irrigation method is commonly used by societies in developing countries. It should be applied only to flat lands that do not concave or slope downhill so that the water can evenly flow to all parts of the field, yet even so, about 50% of the water is wasted and does not get used by the crops. Furrow irrigation is actually a type of flood irrigation in which the water poured on the field is directed to flow through narrow channels dug between the rows of crops, instead of distributing the water throughout the whole field evenly.

4. **Localized irrigation**

Localized irrigation is a system where water is distributed under low pressure through a piped network, in a pre-determined pattern, and applied as a small discharge to each plant or adjacent to it. Drip irrigation, spray or micro-sprinkler irrigation and bubbler irrigation belong to this category of irrigation methods.
UNIT 6
TILLAGE SYSTEMS

Pengenalan Unit

Tillage is mechanical modification of soil structure. Tillage tools modify soil structure through a wide range of soil: tool interactions. Tillage has been part of most agricultural systems throughout history because tillage can be used to achieve many agronomic objectives:

- Soil conditioning (modification of soil structure to favor agronomic processes such as soil seed contact, root proliferation, water infiltration, soil warming, etc.).
- Weed/pest suppression (direct termination or disruption of weed/pest life cycles).
- Residue management (movement, orientation or sizing of residues to minimize negative effects of crop/cover crop residues and promote beneficial effects)
- Incorporation/mixing (placement or redistribution of substances such as fertilizers, manures, seeds, residues, sometimes from a less favorable location to a more favorable spatial distribution).
- Segregation (consolidation of rocks, root crops, soil crumb sizes).
- Land Forming (changing the shape of the soil surface – simplest variant is probably leveling; ridging, roughening and furrowing are also examples).

Objektif Unit

12. Explain the reasons for and effects of tillage.
13. Describe conventional and conservation tillage
TOPIK

1.15 Tillage
   a) Effects of Tillage on soil physical properties
   b) Types of tillage
   c) Conventional Tillage
   d) Conservation Tillage

Isi-isí Penting

1. Primary tillage
2. Secondary tillage
3. Conservation tillage
4. Conventional tillage
5. Mulch till
6. No-till

Pemerhatian/Pandangan/Pendapat
Kesimpulan Unit Tersebut

1. Tillage has three goals: weed control, alteration of physical soil conditions and management of crop residues.
2. Tillage may lead to erosion and soil compaction.
3. Conventional tillage buries crop residues to produce a smooth, residue-free seedbed.
4. Conservation tillage leaves at least 30% of the surface covered by plant residues for control of erosion and preservation of soil water.

Rujukan Tambahan (jika ada)


Latihan 1 / Aktiviti 1

1. Explain the difference between the tillage systems shown in figure below
Latihan dalam kumpulan 1 / Perbincangan 1

Each group will do the assigned readings and discuss among the members based on a list of questions, issues, statements given in the activity sheet. Selected questions or issues will be presented in class.
1. Read the Brief Notes on: Tillage
2. Read pages 383-395 on Soils in our Environment (11th Ed.).
3. Review the power point slides located at the class website
4. Your presentation should focus on the following questions:
   
   e) Describe the following tillage implements: bedder, chisel, coulter, cultivator, disk, harrow and rotary plough.
   f) Discuss the purposes of tillage.
   g) Explain how tillage can directly cause erosion.

Latihan dalam kumpulan 2 / Perbincangan 2

Each group will do the assigned readings and discuss among the members based on a list of questions, issues, statements given in the activity sheet. Selected questions or issues will be presented in class.
1. Read pages 396-401 on Soils in our Environment (11th Ed.).
3. Review the power point slides located at the class website
4. Your presentation should focus on the following questions or issues:
   f) Survey and visit a local farm and find out what tillage systems they use.
   g) Compare and contrast conventional and conservation tillage practices.
Jawapan Latihan 1

1. The increased soil stratification and size and activity of soil organism populations under conservation tillage compared to conventional tillage lead to increased nutrient retention

Jawapan Latihan Dalam Kumpulan / Perbincangan

1. **Soalan 5**: Refer to notes/textbooks
2. **Soalan 4**: Refer to notes/textbooks
Tillage

Tillage is mechanical modification of soil structure. Tillage tools modify soil structure through a wide range of soil: tool interactions. Tillage has been part of most agricultural systems throughout history because tillage can be used to achieve many agronomic objectives:

- Soil conditioning (modification of soil structure to favor agronomic processes such as soil seed contact, root proliferation, water infiltration, soil warming, etc.).
- Weed/pest suppression (direct termination or disruption of weed/pest life cycles).
- Residue management (movement, orientation or sizing of residues to minimize negative effects of crop/cover crop residues and promote beneficial effects)
- Incorporation/mixing (placement or redistribution of substances such as fertilizers, manures, seeds, residues, sometimes from a less favorable location to a more favorable spatial distribution).
- Segregation (consolidation of rocks, root crops, soil crumb sizes).
- Land Forming (changing the shape of the soil surface – simplest variant is probably leveling; ridging, roughening and furrowing are also examples).

Effects of Tillage on soil physical properties:

1. **Soil Structure:** Arrangements of soil particles with crumbly and granular nature is considered good. Best size of soil aggregate for good growth of crop is (1-5mm) smaller aggregates may clog soil pores and larger ones may have large pore space. Tillage improves soil structure when done at optimum soil moisture level. Tilling a soil when it is too wet spoils the structure. Ploughing a dry soil is difficult and will not help in improving structure.

2. **Pore space:** When a field is ploughed the soil particles are loosely arranged and pore space is increased. When the soil is in good tilth the capillary and non capillary pores would be roughly equal. This facilitates free movement of air and moisture in soil.

3. **Bulk Density: (B.D)** When the soil is loosened, the soil volume increase without any affect on weight. BD of Clay soils is low (1.05 m³) and that of sandy soils is high (1.25 – 1.30 m³) and Bulk density of tilled soil is less than that of untilled soil. Particle density is always more than BD.
4. **Soil Colour:** Organic matter is mainly responsible for the dark brown to dark grey colour of the soil. Tillage increases oxidation and decomposition of organic matter resulting in fading of colour.

**Types of Tillage**

<table>
<thead>
<tr>
<th>Types of tillage</th>
<th>Purpose</th>
<th>Implements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary tillage</td>
<td>Create a soil condition from which a seed bed can be prepared using secondary tillage implements. Soil disturbance is generally &gt; 6” deep. Primary tillage is necessary when existing soil conditions prevent the effectiveness of secondary tools.</td>
<td>Moldboard and disk plows invert the soil in a plow layer, resulting in the burial of most crop residues. Aggressive fine tools such as chisel plows, rippers and subsoilers fracture soil but do not invert soil and retain more residue cover. Aggressive rotary powered tools, such as spaders and rotary tillers, can be used for primary tillage. An acceptable seed bed can sometimes be prepared in only one pass.</td>
</tr>
<tr>
<td>Secondary tillage</td>
<td>Seed bed preparation – may involve pulverizing, leveling, and/or residue sizing and burial. Soil preparation is traditionally full field but can be concentrated in row zones.</td>
<td>Tillage tools used for seed bed preparation are generally referred to as “harrows”. Most harrows are draft implements with gangs of tines, disks, rolling baskets or combinations. Powered harrows (e.g. rotovators, rod weeder, reciprocating harrow) are also used for seed bed preparation and can accomplish more in one pass than draft tools.</td>
</tr>
</tbody>
</table>

Conventional tillage, conservation tillage and no-till (or zero-till) are defined by the amount of crop residue left on the ground. Crop residue is the vegetative material, often referred to as trash or litter, left after a crop has been harvested.

**Conventional Tillage**

Conventional tillage incorporates or buries most of the crop residue into the soil. Generally involves plowing or intensive (numerous) tillage trips. Weed control is accomplished with crop protection products and/or row cultivation.
Benefits of Conventional Tillage

1. Conventional tillage has the advantage of increasing porosity and loosening soil, allowing for good air exchange and root growth.
2. It is also an effective way of incorporating manure and breaking up sod fields.

Disadvantages of Conventional Tillage

1. There is limited amount of residue left on fields from conventional tillage and leaves the soils more vulnerable to wind and water erosion.
2. With conventional tillage (complete turning over of the soil), the bare soil is exposed to the erosive action of water, which, in many areas is the major route of soil loss.
3. The greater the level of tillage, the greater the loss of soil organic matter. Organic matter is important for supporting beneficial biologic activity such as bacteria, fungi and earthworms that help cycle nutrients and increase the speed of pesticide breakdown.
4. Drying out the soil,
5. Reducing the size and stability of soil aggregates, which increases the risk of compaction and crusting.

Conservation Tillage

It is any tillage system that maintains 30 percent or more of the soil surface covered with crop/cover crop residue, after planting. Conservation tillage systems include a variety of techniques, including "no-till" "minimum till" "ridge till" "chisel plow" and "mulch till." It is designed to conserve soil, water, energy and protect water quality.

- **No-till or zero tillage** - is a system of conservation tillage in which the soil is left undisturbed by tillage and the residue is left on the soil surface, is the most effective soil-conserving system. Research shows that land left in continuous no-till can eventually create a soil, water and biological system that more closely resembles characteristics of native soils before the advent of agriculture. No-till systems also can provide cover for wildlife if the stubble from the previous crop is left standing.

- **Ridge-till** – The soil is left undisturbed from harvest to planting except for nutrient injection. Planting is completed in a seedbed prepared on ridges with sweeps, disk openers, coulters or row cleaners. Residue is left on the surface between the ridges. Weed control is accomplished with herbicides and/or mechanical cultivation. Ridges are rebuilt during cultivation.

- **Mulch-till** – The soil is disturbed prior to planting. Tillage tools such as chisels, field cultivators, disks, sweeps, and blades are used. Weed control is accomplished with herbicides and/or mechanical cultivation.
Benefits of Conservation Tillage

- Conservation tillage decreases soil erosion, leaching of fertilizer, pesticides and herbicides into the ground water.
- Improved moisture content in soil.
- Healthier, more nutrient-enriched soil.
- More earthworms and beneficial soil microbes.
- Reduced consumption of fuel to operate equipment.
- The return of beneficial insects, birds and other wildlife in and around fields.
- Less sediment and chemical runoff entering streams.
- Reduced potential for flooding.
- Less dust and smoke to pollute the air.
- Less carbon dioxide released into the atmosphere.
- Conservation tillage increases soil infiltration rate and reduces soil evaporation thereby increasing soil water storage.

Plant system

![Plant system diagram]

Figure 1. Plant system

Soil-plant interactions

Local interactions between soil and plant include a broad range of biochemical, chemical and physical processes that occur as a consequence of root growth, water and solute uptake/release by roots and respiration. These soil-plant interactions not only generate mass fluxes between soil and
plants but also affect both the entire plant root morphology and the soil properties. At the field scale, larger-scale variability of the topography, vegetation and soil types or atmospheric conditions may affect how plant and soil interact.

Soil–plant interrelations are dynamic and subject to both inputs (fertilizers, pollutants, soil chemistry) and losses (erosion, leaching, harvesting). In addition to the variety of inputs and outputs, plant nutrients exist in many different forms, or nutrient pools, within the soil. These pools range from soluble, readily available forms, to weakly bound forms that are in rapid equilibrium with soluble pools, to strongly bound or precipitated forms that are very insoluble and become available only over long time periods. Nutrients in solution can be taken up immediately by plant roots, but they also move with water and can easily leach below the plant root zone or be lost in runoff from farm fields.
Figure 3. Soil nutrient pool

Figure 4. Soil-plant microbial relation
Pengenalan Unit

Cropping systems enable the management of crops so as to efficiently use the available climatic and soil resources. The cropping systems that producers use are therefore greatly influenced by the environmental conditions of a region. Socioeconomic and political factors also have a large effect on what producers grow. Soil tillage is a basic part of agricultural production technology.

The Food and Agricultural Organization of the United Nations defines sustainable agriculture as the use of agricultural practices which conserve water and soil and are environmentally non-degrading, technically appropriate, economically viable and socially acceptable.

Sustainable agriculture integrates three main goals--environmental health, economic profitability, and social and economic equity. Sustainability rests on the principle that we must meet the needs of the present without compromising the ability of future generations to meet their own needs.

Sustainable agriculture strives to build a food and fiber production system that is economically viable, while protecting or enhancing environmental quality and the quality of life for consumers and farmers. Farmers and other agricultural professionals work to develop innovative farming techniques and vibrant local economies and markets, while protecting natural resources such as soil and water quality and wildlife habitat.

Sustainable agriculture aims to optimize the use of energy-related inputs. It involves the use of improved cultivars, new crops, efficient cropping systems, improved tools, increased fertilizer use efficiency and systems of integrated pest management. Sustainable agriculture must be economically, environmentally and socially compatible.
Objektif Unit

14. List several cropping/planting systems and relate them to sustainable agriculture

TOPIK

1.16 Planting system
1.2 Sustainable agriculture

Isi-isi Penting

1. Crop rotation
2. Multiple cropping
3. Cover cropping
4. Agroforestry
5. Sustainable agriculture

Pemerhatian/Pandangan/Pendapat
Kesimpulan Unit Tersebut

1. Three cropping systems are commonly used by growers: continuous cropping, crop rotation and multiple cropping.
2. Crop rotation is better for soil and helps prevent erosion.
3. Organic farming replaces chemical fertilizers and pesticides with crop rotation, manuring, cultivation and mineral fertilizers.
4. Planting transgenic (GMOs) crops, through controversial, reduces the threat of weeds and insects.
5. Sustainable agriculture integrates three main goals—environmental health, economic profitability, and social and economic equity.
6. A major problem facing human kind is the production of more food and fibre in the next 40-50 years.
7. A new ecosystem approach is needed in farming to emphasis sustainable agricultural production.

Rujukan Tambahan (jika ada)

4. Sustainable Agriculture: http://www.uky.edu/Ag/CDBREC/introsheets/sustainableag.pdf

Latihan 1 / Aktiviti 1

1. State and defend your position on the use of GMOs.
Latihan dalam kumpulan 1 / Perbincangan 1

1. Read the Brief Notes on: planting systems and sustainable agriculture
2. Read the power point slides located at the class website
3. What is soil quality, how is it measured and of what importance it is to all organisms that live in or on the soil?

Jawapan Latihan 1

1. Refer to materials on internet

Jawapan Latihan Dalam Kumpulan / Perbincangan

1. Soalan 3: Refer to lecture notes/textbooks
Planting system

Cropping systems enable the management of crops so as to efficiently use the available climatic and soil resources. The cropping systems that producers use are therefore greatly influenced by the environmental conditions of a region. Socioeconomic and political factors also have a large effect on what producers grow. Soil tillage is a basic part of agricultural production technology. Some cultural practices specifically developed to enhance the effectiveness of conservation tillage are as follows:

1. Agroforestry and Alley cropping

   Agroforestry is a technique of growing annual food crops in association with woody perennials to optimize the use of natural resources, minimize the need for inputs from nonrenewable resources and reduce the risk of environmental degradation e.g erosion.

   Alley Cropping is a form of agroforestry in which annual crops are grown between adjacent hedgerows of leguminous shrubs and woody perennials. The system is suitable in land degradation.

2. Cover cropping

   Diversifying a cropping system often increases its stability and reduces the incidence of diseases and pests. Growing grass or leguminous cover crops at frequent intervals (once every 2-3 years in the tropics) is necessary in agricultural system. Cover crops have the main advantage of conserving soil tillage systems. They restore fertility, control weeds, conserve rain water and reduce energy cost. They also help to improve soil physical properties including soil tilth and reduce soil erosion.

3. Live Mulch

   A live mulch is a form of mixed cropping. In this system, a fast growing perennial legume is established to smother or suppress weeds and a seasonal grain crop is grown through it in such a way that growth and yield of the food crop is not unduly depressed.
4. **Crop Rotations and Multiple Cropping**

Crop rotation is a planned sequence of different crops grown over years on the same land. Crop rotations vary in length and diversity of crop species. The trend toward simplified crop rotations is possible with synthetic inputs of fertilizers and pesticides. A good example of crop rotations is corn-soybean (2-year rotation). Soybean is a legume; it contributes to biological fixation of nitrogen. Crop rotations provide several advantages including weed control, disease and insect control, rotation effects, and reduced risks. Rotations including perennial legumes such as alfalfa are especially effective at reducing soil erosion and improving soil quality.

**Advantages of Crop Rotation**

(a) Soil fertility & nutrient replacement - as the nutrients in the soil are slowly released, each plant uses them at a different rate, and with more demanding plants or 'heavy feeders' (eg corn) in a crop rotation, the soil has time to build up its nutrient store again. This prevents 'soil exhaustion', otherwise resulting in 'crop starvation', reduced yield and as poor food value.

(b) Pest & disease management – disrupts disease life cycles and the build-up of insect populations. These generally depend upon a specific host plant family to live on and reproduce eg cabbage maggot, carrot wireworm, brassica club-root, potato root eelworm/nematode

(c) Weed control – different species germinate at different times of the year, and the variation in crop depth and surface area covered, as well as bed treatments, can prevent weeds from getting a hold.

**A recommended 4-Year crop rotation**

<table>
<thead>
<tr>
<th>Plot A</th>
<th>Plot B</th>
<th>Plot C</th>
<th>Plot D</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Year 1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leafy Vegetable</td>
<td>Root Crops</td>
<td>Potatoes</td>
<td>Legumes</td>
</tr>
<tr>
<td><strong>Year 2</strong></td>
<td>Potatoes</td>
<td>Legumes</td>
<td>Leafy vegetable</td>
</tr>
<tr>
<td>Root Crops</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Year 3</strong></td>
<td>Legumes</td>
<td>Leafy vegetable</td>
<td>Root Crops</td>
</tr>
<tr>
<td>Potatoes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Year 4</strong></td>
<td>Leafy vegetable</td>
<td>Root Crops</td>
<td>Potatoes</td>
</tr>
<tr>
<td>Legumes</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5. **Summer fallowing**

Summer fallow, sometimes called fallow cropland, is cropland that is purposely kept out of production during a regular growing season. Resting the ground in this manner allows one crop to be grown using the moisture and nutrients of more than one crop cycle. The summer fallow technique provides enough extra
moisture and nutrients to allow the growth of crops which might otherwise not be possible and is closely associated with dry land farming.

Usually this is done in semi-arid regions in order to conserve moisture for the next season. It also provides additional time for crop residues to break down and return nutrients to the soil for the subsequent crop.

6. **Succession Planting**

This is sowing or planting a crop a little at a time to ensure a continuous supply of vegetables throughout the harvesting season, avoiding both lean and glut times.

7. **Interplanting or Intercropping**

This is the practice of planting more than one crop together either in blocks, rows or spaces. It uses all of the available space in the garden at all times.

8. **Catch cropping**

This is a small, quick maturing crop among or alongside main crops which take longer to develop. It is an aspect of interplanting. Some vegetables most effective for catch-cropping are: lettuce, dwarf bean, cress, mustard, chives, celeriac, radish, turnip, corn salad, early carrots.

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**Sustainable Agriculture**

The Food and Agricultural Organization of the United Nations defines sustainable agriculture as the use of agricultural practices which conserve water and soil and are environmentally non-degrading, technically appropriate, economically viable and socially acceptable.

Sustainable agriculture integrates three main goals--environmental health, economic profitability, and social and economic equity. Sustainability rests on the principle that we must meet the needs of the present without compromising the ability of future generations to meet their own needs.

Sustainable agriculture strives to build a food and fiber production system that is economically viable, while protecting or enhancing environmental quality and the quality of life for consumers and farmers. Farmers and other agricultural professionals work to develop innovative farming techniques and vibrant local economies and markets, while protecting natural resources such as soil and water quality and wildlife habitat.

Sustainable agriculture aims to optimize the use of energy-related inputs. It involves the use of improved cultivars, new crops, efficient cropping systems, improved tools, increased fertilizer use efficiency and systems of integrated pest management. Sustainable agriculture must be economically, environmentally and socially compatible.
FIGURE 57
Tillage effects on agricultural sustainability (Lal, 1991b)

- Aggregation (% MWD)
- Porosity (% pore size distribution)
- Infiltration capacity
- Hydraulic conductivity
- Thermal conductivity
- pH curves
- Nutrient and organic matter stratification
- Activity and species diversity of soil fauna and flora
- Biomass carbon
- Soil moisture regime
- Soil temperature regime

- Crusting
- Compaction
- Aeriation
- Erosion
- Leaching and internal drainage
- Mineralization of soil organic matter
- Soil evaporation
- Root development
- Water use efficiency
- Nutrient use efficiency
- Root shoot ratio
- Harvest index
- Economic yield

Issues of agricultural sustainability in fragile lands of marginal ecogregions (Lal, 1991b)

<table>
<thead>
<tr>
<th>Region</th>
<th>Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humid tropics</td>
<td>• High subsistence agricultural usage of the land</td>
</tr>
<tr>
<td></td>
<td>• Reduction in fallow period</td>
</tr>
<tr>
<td></td>
<td>• Soils of low fertility and low yields due to resource-based and no-input agriculture</td>
</tr>
<tr>
<td></td>
<td>• Soil degradation due to fertility, depletion, accelerated erosion, structural deterioration and reduction in soil organic matter</td>
</tr>
<tr>
<td>Arid and semi-arid tropics</td>
<td>• Risks of desertification due to degradation and aridization of soil and environment</td>
</tr>
<tr>
<td></td>
<td>• Perpetual drought stress</td>
</tr>
<tr>
<td></td>
<td>• High risks of crop failure</td>
</tr>
<tr>
<td></td>
<td>• Nutrient deficiency and soils of low fertility</td>
</tr>
<tr>
<td></td>
<td>• Soil compaction</td>
</tr>
<tr>
<td></td>
<td>• Low carrying capacity of land</td>
</tr>
<tr>
<td>Irrigated agriculture in dryland tropics</td>
<td>• Water shortage</td>
</tr>
<tr>
<td></td>
<td>• Salt imbalance and salinization</td>
</tr>
<tr>
<td></td>
<td>• Poor quality irrigation water</td>
</tr>
<tr>
<td></td>
<td>• Deterioration of soil structure</td>
</tr>
<tr>
<td>Steeplands</td>
<td>• Accelerated soil erosion, mass movement and land slides</td>
</tr>
<tr>
<td></td>
<td>• Shallow soils of low fertility</td>
</tr>
<tr>
<td></td>
<td>• Difficulties of mechanizing farm operations</td>
</tr>
<tr>
<td></td>
<td>• Energy shortage</td>
</tr>
<tr>
<td></td>
<td>• Low carrying capacity and low yields</td>
</tr>
</tbody>
</table>
Components of Sustainable Agriculture
Sustainable agriculture can be broken into three components: economic, environmental and social.

1. Economic sustainability
To be truly sustainable, a farm must be economically profitable. The environmental and social benefits of sustainable production methods do not always translate into economic gains. Some farms that operate sustainably may be more profitable than their conventional farming counterparts; however, the reverse can also be true. Many factors aside from crop production methods can affect the bottom line. These can include, among other things, the grower's management strengths/weaknesses, and decision making abilities, and marketing skills. Sustainable agriculture practices can have a positive economic impact on a farm. For example, diversifying the farm with several crops and markets helps to reduce financial risk.

2. Environmental sustainability
Sustainable agriculture also seeks to have a positive impact on natural resources and wildlife. This can often mean taking measures to reverse the damage (e.g. soil erosion or draining of wetlands) that have already occurred through harmful agricultural practices. Renewable natural resources are protected, recycled, and even replaced in sustainable systems.
3. Social sustainability
Social sustainability relates to the quality of life for those who work and live on the farm, as well as those in the local community. Fair treatment of workers, positive farm family relationships, personal interactions with consumers, and choosing to purchase supplies locally (rather than from a more distant market) are just some of the aspects considered in social sustainability. Community supported agriculture (CSA), farmers markets, U-pick, cooperatives, and on-farm events are just some of the ways a sustainable farm can have a positive impact on the local community.

Basic Features and Concepts of Sustainable Systems

1. The need to maintain or improve soil quality and fertility. This is often attained by increasing the organic matter content of the soil, and by minimizing losses from soil erosion.
2. Production programs are designed to improve the efficiency of resource utilization. This will result in the most cost-effective use of water, fertilizers, and pesticides.
3. An attempt is made to improve internal nutrient cycles on the farm, which will reduce the dependence on external fertilizers.
4. Efforts are made to improve biological diversity on the farm. This will result in improved natural suppression of pests, and may also help to improve internal nutrient cycling within the farm.
5. Farm management and marketing programs are designed to minimize overhead costs and to increase returns, often by following alternative marketing schemes.
UNIT 8
SOIL CONSERVATION AND EROSION

Pengenalan Unit

Soil erosion by water, wind and tillage affects both agriculture and the natural environment. Soil loss, and its associated impacts, is one of the most important (yet probably the least well-known) of today's environmental problems. Soil erosion is a natural process. It becomes a problem when human activity causes it to occur much faster than under natural conditions. Soil erosion is common in areas with steep slopes, where trees have been cut down, in droughts when crops and other vegetation grows poorly and in rural areas which are overpopulated.

Soil conservation means the use and preservation of the natural resources of earth and their protection from destructive influences misuse, decay, fire, or waste. The chief causes of soil erosion are water and wind. The aim of soil conservation methods is to prevent soil erosion, prevent soil's overuse and prevent soil contamination from chemicals. There are various measures that are used to maintain soil health, and prevent the above harms to soil. Here are the soil conservation methods which are practiced for soil management.

Objektif Unit

1. Describe how soil erosion occurs and list the types of water and wind erosion.
2. Describe ways to prevent erosion.
3. Calculate soil loss from water erosion on a field.

TOPIK

1.17 Soil conservation
1.18 Soil erosion
1.19 Types of erosion
1.20 Evaluation and prediction of erosion
1.21 Erosion control method, water and soil fertility

**Isi-isi Penting**

1. Gully erosion
2. Sheet erosion
3. Saltation
4. Splash erosion
5. Universal soil loss equation
6. Rill erosion

**Pemerhatian/Pandangan/Pendapat**

**Kesimpulan Unit Tersebut**

1. Soil erosion has been the most devastating environmental disaster.
2. Although natural or geologic erosion is inevitable, man has greatly accelerated the loss of soil by clearing land for farming and for roads and structures.
3. Recently, much progress has been made in developing land management methods to protect the soil.
4. Both the loss of soil and the subsequent sedimentation of the eroded particles are economic and environmental problems.
5. The sediments plug and elevate rivers, fill reservoirs, and suffocate fish.
6. Rain drops detach small soil particles that are then transported from their location in flowing water.
7. The extent of erosion due to rain is affected by rainfall intensity, the soil erodibility, the length and slope of the field and farming or land shaping practices used.
8. The Universal Soil Loss Equation and other models use these factors to predict annual soil loss.
9. Both wind and water erosion can be controlled somewhat by improving soil structure, by crop selection, by leveling the land, by using cover crops and by construction of buffer strips.
10. The most powerful and practical tool for soil erosion control is vegetative cover.
11. Cropping and tillage systems that produce and retain substantial amounts of soil cover can minimize soil erosion.

Rujukan Tambahan (jika ada)


Latihan 1 / Aktiviti 1

2. Describe the type of soil erosion shown in the figure below.
Latihan dalam kumpulan 1 / Perbincangan 1

Each group will do the assigned readings and discuss among the members based on a list of questions, issues, statements given in the activity sheet. Selected questions or issues will be presented in class.

1. Read the Brief Notes on: Soil Erosion.
2. Read pages 356-363 on Soils in our Environment (11th Ed.).
5. Review the power point slides located at the class website
6. Your presentation should focus on the following questions:

   h) List practices that decrease the detachment of soil by rain drops.
   i) Explain the distinction between geologic erosion and accelerated erosion.
   j) Describe the three main steps in the water erosion process.
   k) What parts of your country suffer the most water erosion problems? Explain.

Latihan dalam kumpulan 2 / Perbincangan 2

Each group will do the assigned readings and discuss among the members based on a list of questions, issues, statements given in the activity sheet. Selected questions or issues will be presented in class.

1. Read pages 369-380 on Soils in our Environment (11th Ed.).
2. Read pages 762-790 on Nature and Properties of Soils (14th Ed.).
4. Review the power point slides located at the class website
5. Your presentation should focus on the following questions or issues:

   h) Define and briefly discuss these terms: 1) highly erodible land and 2) erosivity index.
   i) Describe the characteristics of vegetative cover that would generally allow the least soil erosion.
Jawapan Latihan 1

1. Gully erosion, which means the loss of large volumes of soil. Deep wide gullies, sometimes reaching 30m deep, severely limit the use of the land, while off-site deposition of soil causes water-quality decline in streams or rivers and sedimentation of dams and reservoirs. Large gullies disrupt normal farm operations, creating access problems for vehicles and stock. Major concentrations of high-velocity run-off water in these larger rills remove vast amounts of soil. This results in deeply incised gullies occurring along depressions and drainage lines.

Jawapan Latihan Dalam Kumpulan / Perbincangan

1. Soalan 6: Refer to lecture notes/other reference materials
2. Soalan 5: Refer to lecture notes/other reference materials
Soil Conservation
Soil conservation means the use and preservation of the natural resources of earth and their protection from destructive influences misuse, decay, fire, or waste. The chief causes of soil erosion are water and wind. There are various measures that are used to maintain soil health, and prevent the above harms to soil.
Soil and water conservation is necessary for sustained productivity of land. Soil erosion is prevented or reduced to a tolerable level, and water is conserved for judicious utilization. Sustainable production implies that agricultural practices would lead to economic gains without impairing environmental quality and the usefulness of the soil for future generation. Therefore, the objectives for soil and water conservation are:
- promotion of proper land use
- prevention of soil erosion
- restoration of the productivity of eroded land
- maintenance of soil productivity
- maintenance of environmental quality by preventing land and water pollution

Principles of soil conservation:
1. To protect soil from the effects of rain drops.
2. To slow down the flow of water when it flows on slope.
3. Reductions of wind velocity near the places grow vegetation cover.
4. To grow vegetation cover which might catch and hold the moving particles of soil?
5. To increase soil fertility and productivity.

- Soil conservation as a combination of controlling erosion and maintaining soil fertility.
- Sustainable agriculture integrates three main goals--environmental health, economic profitability, and social and economic equity.
• A major problem facing human kind is the production of more food and fibre in the next 40-50 years.
• A new ecosystem approach is needed in farming to emphasis sustainable agricultural production.
• Agronomic or biological measures utilize the role of vegetation in helping to minimize the erosion by increasing soil surface cover, surface roughness, surface depression storage and soil infiltration. Some examples are: Strip cropping/alley cropping/hedgerow intercropping.
• Soil management is concerned with ways of preparing the soil to promote dense vegetative growth and improve the soil structure so that it is more resistant to erosion. Some techniques included in this group are: minimum tillage, crop rotation (food crops/cover crops), manure, sub-soiling and drainage.
• Mechanical or physical methods can be viewed as an attempt to control the energy available for erosion (rain splash, runoff). These methods depend on manipulating the surface topography by installing terraces, ditches.

Soil conservation practices are tools the farmer can use to prevent soil degradation and build organic matter. These practices include: crop rotation, reduced tillage, mulching, cover cropping and cross-slope farming.

Soil Erosion
Soil erosion is the removal of soil from soil surface by the action of water or wind. Naturally, it is a smoothing or leveling process with soil and rock particles being carried, rolled and washed downstream under the influence of wind, water and gravity.
Erosion is caused by natural or human factors. Human factor in soil erosion are: deforestation, over-grazing, construction activities and mining activities.

Types of Erosion
There are three main types of erosion:

1. Mass movement
This involves the downward movement of soil and rock under the assistance of gravity.
There are many forms of mass movement including soil creep, earth flow, slumps, landslips, landslides and rock avalanches. Although relatively infrequent, large mass movement events are dramatic, resulting in permanent loss of houses, roads and agricultural land.
Landslips, slides and earth flows occur on steep slopes with high clay content. It is triggered by over-saturation of soils from excessive rainfall. Rainfall increases soil weight, and lubricates layers within the soil.
2. Water erosion

Water erosion is a two-part process involving the detachment and transport of soil particles. The water erosion process consists of discrete stages from rain drop impact to the formation of gully erosion. Each stage has its own processes and characteristics. Controlling or preventing water erosion requires an understanding of each step in the erosion process.

There are three steps to accelerated erosion by water:

1) **Detachment** or **loosening** of soil particles caused by flowing water, freezing and thawing of the topsoil, and/or the impact of falling raindrops.

2) **Transportation** of soil particles by floating, rolling, dragging, and/or splashing.

3) **Deposition** of transported particles at some place lower in elevation.

Forms of Water erosion

- **Splash erosion** or rain drop impact represents the first stage in the erosion process. Splash erosion results from the bombardment of the soil surface by rain drops. Rain drops behave as little bombs when falling on exposed or bare soil, displacing soil particles and destroying soil structure.

- **Sheet erosion** occurs as a shallow 'sheet' of water flowing over the ground surface, resulting in the removal of a uniform layer of soil from the soil surface. Sheet erosion occurs when rainfall intensity is greater than infiltration (sometimes due to crusting).

- **Rill erosion** results from the concentration of surface water (sheet erosion) into deeper, faster-flowing channels. As the flow becomes deeper the velocity increases detaching soil particles and scouring channels up to 30cm deep. Rill erosion represents the intermediate process between sheet and gully erosion.

- **Gully erosion** is responsible for removing vast amounts of soil, irreversibly destroying farmland, roads and bridges and reducing water quality by increasing
the sediment load in streams. Once established, gully erosion can be difficult to control. In most cases a combination of approaches, including the use of vegetation, fencing, diversion banks and engineering structures are required.

3. Wind erosion

Wind erosion involves the detachment, transportation and re-deposition of soil particles by wind. Wind erosion is common on flat, bare areas with dry, sandy soils, or anywhere the soil is loose, dry, and finely granulated. Sandy soils are very susceptible to erosion, however clay soils which have been pulverised by powered tillage implements or worked when they are too dry are also susceptible to wind erosion.

The erodibility of soils can be described as their sensitivity to the effects of wind and water on the soil structure. This property is expressed as an erodibility index, where low values indicate high susceptibility to erosion, and high values correspondingly indicate a low susceptibility to erosion.

The erodibility index is determined by combining the effects of slope and soil type, rainfall intensity and land use. These aspects are represented by terrain morphology (soil and slope), mean annual rainfall and broad land use patterns.

Management practices that reduce erosion:

- Increase vegetative cover, especially close to the soil surface
- Increase the content of soil organic matter which helps improve soil structure
- Increase soil roughness
- Plant windbreaks and shelterbeds to reduce wind erosion
- Use contour furrows, terraces, plowed strips, and/or ridges to reduce or deflect runoff.

Methods of Controlling Soil Erosion

Crop Rotation: Crop rotation decreases soil loss and preserves the productivity of land. By the same crop year by year depletes the soil mineral.

Strip Cropping: It involves the planting of crop in rows to check the flow of water.

Terracing: Here slope is made to several flat strips for plantation and cultivation. The method of dividing slope into several flat fields is called terracing and each of
the terrace works as an embankment of earth, built across the slope to control runoff and reduce erosion.

**Aforestation:** By the process of a forestation establishment of new forests is one of the methods for soil conservation. Planting on land is the successful method for soil conservation.

**Planning of wind break trees:** It is also one of method to check soil erosion. So strong tall plants should be planted densely, as a boundary on the fields.

**Evaluation and prediction of Erosion**
Soil erosion occurs at widely varying rates over the landscape or a field. Direct measurement is impractical and difficult to measure. Variety of erosion prediction methods is available; each is best at performing a particular task; no single prediction method meets all needs. Must consider major factors of climate, soil, topography and land use.

1. **REVISED UNIVERSAL SOIL LOSS EQUATION (RUSLE)**

RUSLE is an erosion prediction model that predicts longtime average annual soil loss resulting from raindrop splash and runoff from specific field slopes in specified cropping and management systems and from rangeland. The equation of the model is:

\[ A = RKLSCP \]

- **A** = Annual Soil Loss in mt/ha
- **R** = Rainfall factor
- **K** = Soil erodibility constant
- **LS** = Slope percentage and length factor
- **C** = Cropping/cover factor
- **P** = Cultural practice

Developed by the USDA-Agricultural Research Service, and first released in 1993, this technology has been implemented in field offices of the USDA-Natural Resources Conservation Service and is being used nationally and internationally for prediction of erosion.

2. **WATER EROSION PREDICTION PROJECT (WEPP)**

The WEPP model is a process-based, distributed parameter, continuous simulation, erosion prediction model for use on personal computers. The model is applicable to hill slope erosion processes (sheet and rill erosion), as well as simulation of the hydrologic and erosion processes on small watersheds.
3. WIND EROSION PREDICTION EQUATION (WEQ)

This model shows how wind erosion is a function of five factors and their interactions.

\[ E = f (I \ C \ K \ L \ V) \]

Where...

\( E \) = Predicted soil loss due to wind erosion
\( I \) = Soil erodibility factor
\( C \) = Local wind erosion climate factor
\( K \) = Roughness factor
\( L \) = Length of field factor
\( V \) = Vegetative cover factor

4. OTHER MODELS

- **ANSWERS** (Areal nonpoint source watershed environment response simulation, 1980)
- **SWAT** (Soil and Water Assessment Tool) - simulate impact of contrasting scenarios of land use and tillage cropping systems on non-point source pollution.
- **EPIC** (Erosion productivity impact calculator – estimate crop yield reduction due to erosion).
- **GUEST** (Griffith University Erosion System Template, Yu 2003): estimates erosion based on the simultaneous transport and deposition processes.
- **EUROSEM** (European Soil Erosion Model, Morgan 1998); compute sediment transport, erosion and deposition over land surface throughout a storm; it can be applied to individual fields or small catchment; simulates interrill erosion.

Erosion Control Methods, Water and Soil fertility

A. Vegetative methods:

- Hydroseeding, and mulching
- High density planting
- Multiple cropping
- Cover cropping Maintain crop residue cover e.g planting of cover crops to prevent detachment of soil by rain drops.
- Soil conditioners e.g polymers
- Strip cropping
- Agroforestry
- Maintain organic matter
B. mechanical methods:
- Terracing
- Diversion structures/waterways e.g check dam, trap sediments.
- Protect surface soils with geotextiles or mulch.
- Conservation tillage. Conservation tillage is any tillage planting system that leaves at least 30% of the field surface covered with crop residue after planting is completed.

Types of Conservation Tillage
- No till planting
- Strip rotary tillage
- Till planting
- Mulch tillage
- Reduced tillage
- Contour bund
- Contour tillage
- Minimum tillage

The concept of the conservation of soil takes into account, the strategies for preventing the soil from getting eroded and preventing it from losing its fertility due to an adverse alteration in its chemical composition.
A. Soil Sampling and Preparation

The soil sample must perfectly represent the area. Variation in slope, color, texture, crop growth and management should be taken into account and separate sets of composite samples need to be collected from each of such area. The method of soil sampling to be used and the amount of soil to be taken mainly depends on the purpose for which sample is required, the nature of soil and the time available. Main purpose for which samples are collected is for soil fertility evaluation and fertilizer recommendation.

A field can be treated as a single sampling unit or composite sample only if it is more or less uniform in all respect. Sampling For fertility evaluation and fertilizer recommendation, the sample should be collected separately from areas which differ in soil color or past management, e.g., liming, manuring, fertilization, cropping pattern, etc.

Tools and Materials

- Soil tube auger, screw type auger, post-hole auger, spade are used for taking samples. Tools for collecting the samples should be free from rust or any foreign material, which may contaminate the samples.
- A bucket for collecting and mixing the composite sample.
- Clean, well-labelled bags for storing the soil sample.

Preparation of soil samples

1. **Air-drying**: Air-drying usually takes one week. During air-drying, avoid contamination.

2. **Grinding**: Grind the sample in a mortar using porcelain-capped pestle.

3. **Sieving**: Sieve the soil through a 2 mm stainless steel sieve.

4. **Mixing and storage**: Mix samples thoroughly, then store in clean closed containers (i.e. polyethylene bags or bottles) and label the containers.
B. Water sampling and Preparation

Sample storage and preservation
Samples that are not analyzed immediately must be protected from contaminants or loss of determinants. For this purpose, sample bottles should be chosen for long term storage with little or no changes to sample composition.

Water Sampling
Sample bottles shall be labeled indelibly prior to sampling with a unique sample number, the location, date and analyses required.

<table>
<thead>
<tr>
<th>Test</th>
<th>Sample Bottle</th>
<th>Wash</th>
<th>Storage &amp; Transport</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbidity</td>
<td>Polyethylene</td>
<td>Detergent then Dist H₂O</td>
<td>Store at 1-4°C</td>
</tr>
<tr>
<td>Colour</td>
<td>Polyethylene</td>
<td>Detergent then Dist H₂O</td>
<td>Store at 1-4°C. Test within 48 hrs.</td>
</tr>
<tr>
<td>Major Ions</td>
<td>Polyethylene</td>
<td>Dist H₂O</td>
<td></td>
</tr>
<tr>
<td>Nutrients</td>
<td>Polyethylene</td>
<td>Dist H₂O</td>
<td>May be frozen, or test within 24 hrs.</td>
</tr>
<tr>
<td>Suspended and Solids</td>
<td>Polyethylene</td>
<td>Detergent then Dist H₂O</td>
<td>Store at 1-4°C. Test within 24 hrs.</td>
</tr>
<tr>
<td>Heavy Metals</td>
<td>Polyethylene</td>
<td>Acid wash then rinsed with Dist H₂O</td>
<td>Store at 1-4°C</td>
</tr>
<tr>
<td>Pesticides</td>
<td>Amber Glass</td>
<td>Acid wash then rinsed with Dist H₂O</td>
<td>Store at 1-4°C</td>
</tr>
<tr>
<td>Herbicides</td>
<td>Amber Glass</td>
<td>Acid wash then rinsed with Dist H₂O</td>
<td>Store at 1-4°C</td>
</tr>
<tr>
<td>Bacteria</td>
<td>Sterile IDEXX jars</td>
<td>Do not wash. Fill to the mark only.</td>
<td>Transport at 4° C. Test within 6 hours.</td>
</tr>
<tr>
<td>Chlorophyll</td>
<td>Opaque Polyethylene</td>
<td>Dist H₂O. Fill to the shoulder only.</td>
<td>Transport at 4° C.</td>
</tr>
</tbody>
</table>
SOIL AND TISSUE ANALYSIS

Soil testing and plant tissue analysis are similar in that they both measure nutrients necessary for plant growth. Soil samples supplement tissue samples by providing information on soil fertility, pH and soluble salts. Plant analysis reports provide valuable data for making fertilizer management decisions as well as an excellent record of crop nutrient use and needs from year to year under different environmental conditions.

TOTAL NITROGEN IN PLANT AND SOIL (KJELDAHL METHOD) OR DRY COMBUSTION METHOD

Equipment
1. Analytical balance
2. Acid fume hood
3. Digestion heating block
4. Volumetric digestion tubes, 100 mL
5. Pipette dispenser
6. Micro-kjeldahl steam distillation apparatus
7. Burette (10 mL)
8. Graduated beakers

Reagents
1. Catalyst Mixture (K₂SO₄ - CuSO₄ . 5H₂O - Se), 100:10:1 w/ w ratio
2. Concentrated H₂SO₄
3. Sodium Hydroxide Solution (NaOH), 10 N
4. Boric Acid Solution (H₃BO₃) plus indicator
5. Deionized water.

Procedure

A. Digestion
1. Weigh 1 g for soil and 0.5 g for plant tissue in a digestion tube.
2. Add 2 g scoop of catalyst and 10 mL concentrated H₂SO₄.
3. Place the digestion tubes in the digestion block.
4. Raise the temperature to 220° and maintain it for 1.5 hours, then raise the temperature to 360° for 3.5 hours.
5. After digestion is complete, cool the samples overnight.
6. Slowly and with swirling, add 25 mL deiodized water to each tube, cool, and bring to volume with DI water.
7. Filter with filter paper No. 2 and collect the filtrate.
8. Send the filtrate to Auto analyzer for determination of total N.
B. Distillation

1. Place a 100 mL graduated beaker with 5 mL 2% boric acid under the condenser so that the tip of the with the tip touching the solution surface.
2. Pipette 10 mL 10 N sodium hydroxide solution through the distillation head.
3. Immediately attach the flask to the distillation unit with a clamp, start distillation, and continue for 3 minutes. Lower the dish to allow distillate to drain freely into the dish.
4. After 4 minutes when about 35 mL distillate is collected, turn off the steam supply, and wash tip of the condenser into the evaporating dish with a small amount of DI water.
5. Titrate the distillate to pH 5.0 with standardized 0.01 N H\textsubscript{2}SO\textsubscript{4}. The color change at the endpoint is from green to pink (pH ≈ 5.4).

Calculations

\[
\% \text{ N} = \frac{14.01 \times (\text{ml titrant} - \text{ml blank}) - (\text{N of titrant}) \times 100}{\text{Sample Wt. (grams)} \times 1000}
\]

Total Soil Carbon Analysis (Dry Combustion Method)

Organic Carbon is contained in the soil organic fraction, which consists of the cells or microorganisms, plant and animal residues at various stage of decomposition, stable humus synthesized from residues and highly carbonized compounds such as charcoal. The amount of organic carbon is related to organic matter. Determination of total organic Carbon content is used as a measure for soil organic matter (SOM) content. It is often determined by either the K\textsubscript{2}Cr\textsubscript{2}O\textsubscript{7} wet combustion method or by the dry combustion method. The dry combustion method gives absolute values and is useful for accurate estimation of organic and total Carbon.

Dry Combustion Method

Materials:

1. Mortar and Pestle
2. Sieve, 1 mm
3. Crucible
4. Total Carbon Analyzer

Methods:

1. Crush the air dried soil and pass through 60 mesh sieve.
2. Weigh 2.0 g of the soil into a crucible.
3. Send the soil to the Total Carbon Analyzer for dry combustion.
Exchangeable Soil P analysis (Bray 2 Method)

Phosphorus is extracted from the soil using Bray 2 solution as extractant. The extracted phosphorus is measured colourimetrically, based on the reaction with ammonium molybdate and development of the ‘Molybdenum Blue’ colour. The absorbance of the compound is measured at 882 nm in a spectrophotometer and is directly proportional to the amount of phosphorus extracted from the soil. The extraction of soil P by the Bray P2 method is based upon the solubilization effect of H⁺ ions on soil P and the ability of the F⁻ ion to lower the activity of Al³⁺.

Extraction Reagents
Ammonium Fluoride (1 N NH₄F)
Weigh 37 g ammonium fluoride NH₄F into a 1000 mL volumetric flask and bring to volume with water.

Hydrochloric acid (0.5 N HCl)
Dilute 20.4 mL concentrated HCl to 500 mL water.

Extraction Reagent Preparation
Mix 30 mL 1 N NH₄F with 200 mL 0.5 N HCl in a 1000 mL volumetric flask and dilute to volume with water. This solution is 0.03 N in NH₄F and 0.1 N in HCl, has a pH of 2.6.

Materials
1. Plastic vial, 100 mL
2. Filter Paper No. 2
3. Bray 2 Extracting Solution (0.1N HCl + 0.03N NH₄F)

Procedure
1. Weigh 2.0 g of air-dried soil into a plastic vial.
2. Add 14 mL extraction reagent (0.1N HCl + 0.03N NH₄F) and shake for 5 minutes on a reciprocating shaker.
3. Filter through filter paper No. 2.
4. Send the filtrate to Auto Analyzer (AA) for P determination.

Extractable Micronutrients (Fe, Cu, Zn, Mn) (Dilution Double Acid Method)

Materials:
1. Conical flask, 100 mL
2. Plastic vial, 100 mL
3. Filter Paper No. 2
4. Mechanical Shaker
5. Diluted Double Acid Extracting Reagent (Mehlich No. 1 Extracting Reagent)
   – (0.05 N HCl + 0.025 N H₂SO₄)
Methods:
1. Weight 5 g of air-dried soil (2.0 mm) into conical flask.
2. Add 25 mL of Diluted Double Acid Extracting Reagent (0.05 N HCl + 0.025 N H₂SO₄).
3. Shake well for 15 minutes on a mechanical shaker at 180 rpm.
4. Filter with filter paper No. 2 and collect the filtrate.
5. Send the filtrate to Atomic Absorption Spectrophotometer (AAS) for determination.

PLANT TISSUE ANALYSIS OF P, K, Ca, Mg, Fe, Zn & Mn (DRY ASHING METHOD)

Dry ashing is conducted in a muffle furnace at temperatures of 500 to 550 °C for 4 to 8 hours. For tissue high in carbohydrates and oils, ashing aids may be required to achieve complete decomposition of organic matter. At the end of the ashing period, the vessel is removed from the muffle furnace, cooled, and the ash is dissolved in dilute nitric (HNO₃) or hydrochloric acid (HCl), or a mixture of both, such as dilute aqua regia. The final solution is diluted as needed to meet the range requirements of the analytical procedure or instrument utilized.

Reagents and Apparatus

1. Conc. HCl (6 N)
2. HNO₃ (20% vol./vol).
3. Muffle furnace
4. 15 ml crucibles
5. Glass tubes

Procedure
1. Weigh 1 g of plant sample in a porcelain crucible and place in a muffle furnace.
2. Slowly raise the temperature of the muffle furnace to 550°C and ash at this temperature for a minimum of 4 h till white or grayish white ash is obtained.
3. Remove the crucible out of the furnace and leave to cool.
4. Then moisten the ash with a few drops of deionized water and add 2 mL of conc. HCl.
5. Then add 2.5 mL of 2 M HNO₃ and place in a water bath for one hour.
6. The mixture is then transferred to 100ml volumetric flask.
7. The crucible is rinsed several times to ensure that all the mixture is transferred to the volumetric flask.
8. Then make up volume with deionized water, shake, filter using filter paper No. 2 and analyze for P, K, Ca, Mg and micronutrients.
ANALYSIS OF WATER CONTENT AND MOVEMENT IN SOIL
Soil moisture content indicates the amount of water present in the soil. The movement of water into the soil layer is called Infiltration. The rate of this movement is called the infiltration rate. If rainfall intensity is greater than the infiltration rate, water will accumulate on the surface and runoff will begin. Movement of water into the soil is controlled by gravity, capillary action, and soil porosity. The soil moisture content can also be expressed in mass or volume basis. Measurement of soil water content (volume and mass basis) must begin with measurement of soil bulk density. **Bulk density** is a measure of the weight of the soil per unit volume of soil.

A) MEASUREMENT OF SOIL WATER CONTENT

**Materials**
1. Core ring (cylindrical metal ring with plastic caps).
2. Hammer
3. Oven
4. Weighing balance

**Procedure**
1. Push or hammer a core ring (measuring 7.6 and 4.0 cm in diameter and depth, respectively, and having a known weight) into the soil to the desired soil depth.
2. Carefully remove the core ring from the soil and trim excess soil to the level of both ends of the core ring. Clean outside of the ring of any remaining soil.
3. Close both ends of the ring with the plastic caps and bring back to the laboratory for analysis.
4. Weigh the soil with the core ring (without plastic caps), then oven dry at 105° for at least 24 hours. Weigh the soil with core ring again.

**Calculations**

1. **Bulk density** $\rho_b$ (g cm$^{-3}$):

\[
\rho_b = \frac{W_b - W_r}{\pi h d^2/4}
\]

Where $W_b$ is the weight of the soil and core ring after oven-drying (g); $W_r$ is the weight of the core ring (g), $h$ is the core ring height or depth (cm); and $d$ is the core ring diameter (cm).
2. Soil water content $\theta_w$, expressed on a dry basis:

$$\theta_w = \frac{W_a - W_b}{W_b - W_f}$$

Where $W_a$ is the weight of the soil and core ring before oven drying (g).

3. Soil water content $\theta_v$, expressed on a volume basis:

$$\theta_v = \theta_w \rho_b$$

B) WATER INFILTRATION IN SOIL (See page 18-22, Soil Physics Analyses, vol. 1)
Lab 4
Measurement and prediction of soil erosion

MEASUREMENT AND PREDICTION OF SOIL EROSION USING PROTABLE RAINFALL SIMULATOR (See page 34-37, Soil Physics Analyses, vol. 1)
ANALYSIS OF NUTRIENTS IN RIVER AND WATER RESOURCES FOR IRRIGATION

Water quality is affected by a wide range of natural and human influences. The most important of the natural influences are geological, hydrological and climatic, since these affect the quantity and the quality of water available. The effects of human activities on water quality are both widespread and varied in the degree to which they disrupt the ecosystem and/or restrict water use. Pollution of water by human e.g. over application of chemical fertilizers may lead to problems such as eutrophication, algal bloom in water.

The quality of water may be described in terms of the concentration and state (dissolved or particulate) of some or all of the organic and inorganic material present in the water, together with certain physical characteristics of the water. The chemical analysis of water provides considerable insight into the health and workings of lakes, rivers, oceans, and groundwater. The results of analyses performed on a single water sample are only valid for the particular location and time at which that sample was taken.

A. Measurement of pH and EC of Irrigation Water

pH value is the logarithm of reciprocal of hydrogen ion activity in moles per liter. In water solution, variations in pH value from 7 are mainly due to hydrolysis of salts of strong bases and weak acids or vice versa. Dissolved gases such as carbondioxide, hydrogen sulphide and ammonia also affect the pH of water. The overall pH range of natural water is generally between 6 and 8. pH lower than 4 will produce sour taste and higher value above 8.5 bitter taste.

EC is a quick way to measure the total salts in the soil, both 'good' salts for the irrigator like nitrate and potassium and 'bad' salts like sodium and chloride. Salts can accumulate in either a soluble or insoluble form. Plants can only absorb soluble salts. Only soluble salts conduct electricity so that the conductivity of a solution gives a good guide to the salt content of water or growing media.

Irrigation water can be measured directly, but the soluble salt content of soils or potting media can only be determined by extracting the salts into solution and then measuring the level of salt in the extract. By convention, electrical conductivities are measured at 25°C. Electrical conductivities are measured in dS/m. In practice, the quantities of salt measured are small so the results may be given as milliSiemen/cm (mS/cm) or microSiemen/cm (S/cm). 1 S = 1000 mS = 1 000 000 S. Older machines may give readings in mho/cm. This is equivalent to dS/m or S/cm.

Irrigation water should have an EC of less than 0.8 dS/m. Water with an EC of between 0.8 and 2.3 dS/m (500-1500 ppm) is considered marginal for irrigation. The water will not taste salty, but salt levels will build up quickly in the soil and need to be managed carefully. Water with an EC greater than 2.3 dS/m is generally not suitable
for irrigation. Crops that are sensitive to salt, like beans, clover or plums may experience reduced yield when the EC of the soil water increases above 1 to 1.5 dS/m. Crops tolerant to salt, like cotton and barley, can withstand EC levels over 7 dS/m. For comparison, sea water has an EC of 54 dS/m.

Methodology
1. Collect about 50 mL of irrigation water in a plastic vial.

2. Filter with filter paper No. 2 and take pH and EC readings using pH and EC meters.

B. Measurement of Nutrients concentration in Irrigation water
The water quality used for irrigation is essential for the yield and quantity of crops, maintenance of soil productivity, and protection of the environment. All irrigation water contains essential plant nutrients. These nutrients are free bonuses from a crop production standpoint. However, some nutrients can be present in amounts that will be toxic or damaging to crop growth.

A laboratory analysis will provide information on irrigation water quality. Most irrigation water analyses will include: sodium adsorption ratio (SAR); total dissolved solids; concentration of specific anions, especially bicarbonate, chloride and sulfate; concentrations of specific cations, especially sodium, magnesium and calcium; and pH value of the water.

The most common irrigation water quality problems are caused by excessive amounts of salt (salinity) and sodium (alkali). Besides being toxic to crop growth, excess salt can restrict the capability of plants to extract sufficient water from the soil. Excessive amounts of sodium can cause soil particles to disperse, thereby destroying soil structure and restricting the movement of water and air through the soil.

Some water may contain sufficient chloride and bicarbonate to cause damage to certain crops when applied through sprinkler systems. Often when these hazards exist, problems are avoided by developing appropriate management practices.

Methodology
1. Collect about 50 mL of irrigation water in a plastic vial.

2. Filter with filter paper No. 2 and analyze for calcium, magnesium, potassium, phosphate, iron, copper, zinc and manganese.
Lab 6
Analysis of data and interpretation for soil fertility and water quality
Lab 7
Farm visit to evaluate integrated soil management/ film show/ case study