Module 3

Carbon and Organic Matter

This is the 3rd module of a training course titled:
Submerged Soils for Rice Production

An interactive version of this presentation can be viewed at this site:

http://www.knowledgebank.irri.org/submergedsoils

Intro to Module 3

Carbon (C) and its processes are essential to life and agricultural production. They also play a direct role in our changing global climate.

- Purpose: To review basics of C and highlight C processes related to rice production in submerged soil.

Module 3

Lesson 1 – Focusing on carbon

- Question: Why is carbon important to us?
- Objective: Identify some important functions of carbon in life around us.

Module 3

Lesson 1 - Carbon around us

- C bonds form the skeleton for all living things
  - C is the second element by weight in the human body
  - 40% of dry weight in plants is C
- It forms millions of compounds
  - Some are common like carbon dioxide (CO_2)
  - Others are precious resources like diamonds, petroleum, natural gas
- It is the fourth most abundant element in the universe

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Lesson 1 - The carbon cycle

Carbon may:

- remain in a particular form for thousands of years
- be transformed into countless variations as it passes through land, water, and atmosphere

The carbon cycle includes:

- C in storage (sediment, soils, fossil fuels, etc.)
- C transitioning from one form to another (C forms in atmosphere, C compounds in plant and animal life, etc.)
- the processes that cause C to change form

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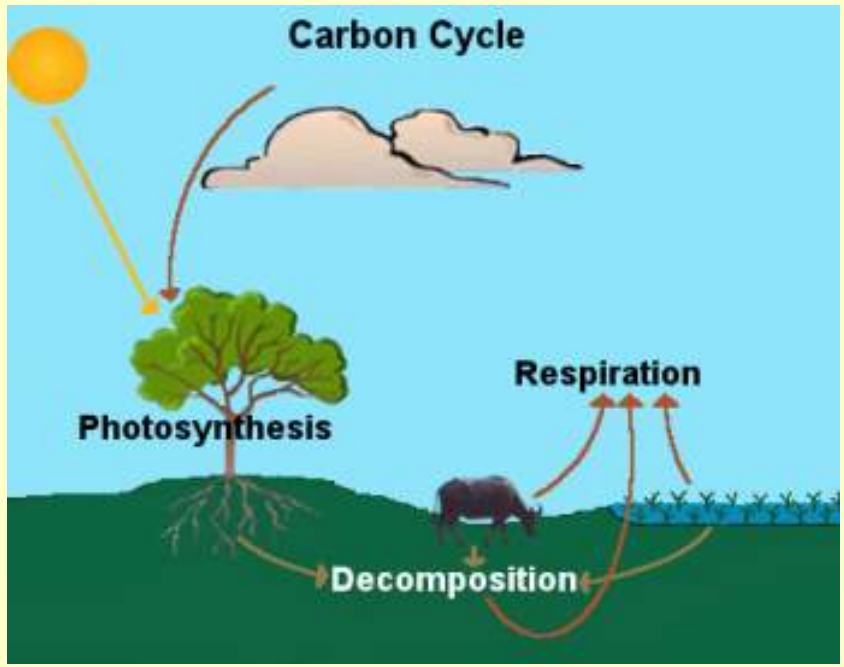
Lesson 1 – Processes of the carbon cycle (1)

Photosynthesis and respiration are key processes of the C cycle.

- Photosynthesis – Green plant tissues capture the sun's energy to power a reaction that combines CO_2 and H_2O into C compounds for storable energy

- Respiration – Living organisms break down C compounds to create energy; CO_2 and H_2O return to the atmosphere.



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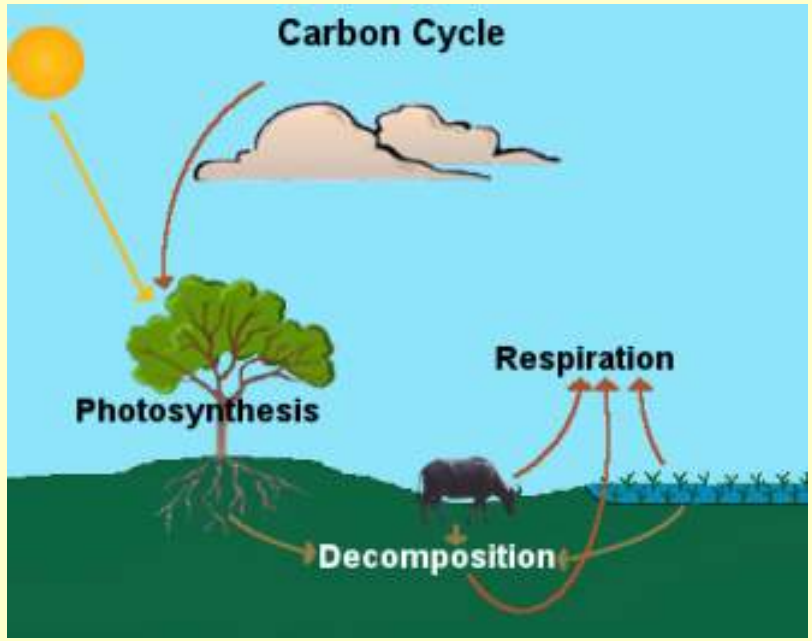
Lesson 1 – Processes of the carbon cycle (2)

Decomposition is also a key process of the C cycle.

- It breaks down C compounds produced during growth
  - sugars, starch, protein, cellulose, fats, lignin, etc.
- It results in energy for macro- and micro-organisms
  - animals, arthropods, fungus, nematodes, bacteria, etc.
- CO_2 and stable organic matter are products of decomposition



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Lesson 1 – Summary slide

- C is an important component for all life and it forms millions of compounds
- Because of the C cycle, C is recycled and reused by all of the organisms on earth
- Photosynthesis, respiration, and decomposition are important biological processes of the C cycle

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Lesson 1 – Question to consider

Carbon levels in the atmosphere are increasing as a result of human activities like burning fossil fuels and making cement. Carbon stored underground for thousands of years is returned to the atmosphere.

- In what ways could life around you be affected by increased C in the atmosphere?

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Lesson 2 – Forms of carbon

- Question: What C forms are found where rice is produced in submerged soil?
- Objective: Be able to discuss carbon forms and the processes causing C to change forms.

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Lesson 2 - Carbon in the rice plant

- Photosynthesis and respiration provide plants with carbohydrates and energy for growth
- During plant growth, many C compounds are formed including:
  - Sugar, protein, cellulose, wax, and lignin

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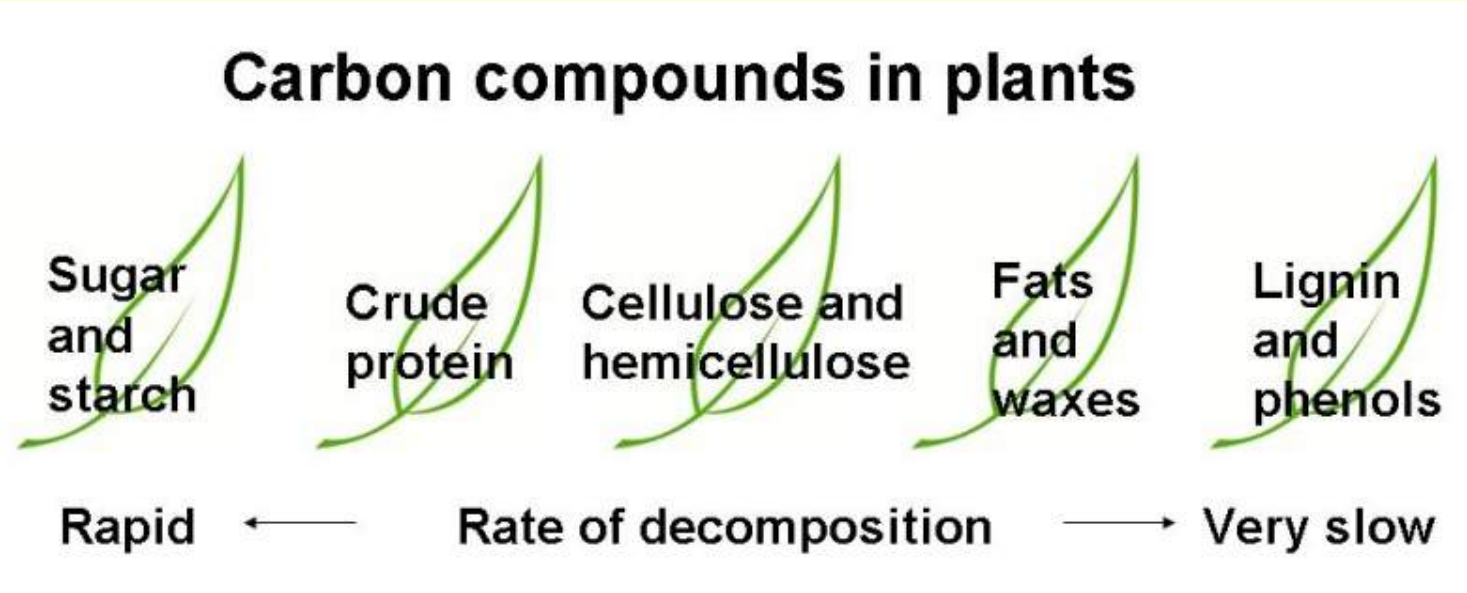
Lesson 2 – Breaking down carbon compounds

- When a plant dies, C compounds developed during growth are broken down
- These compounds decompose at different rates



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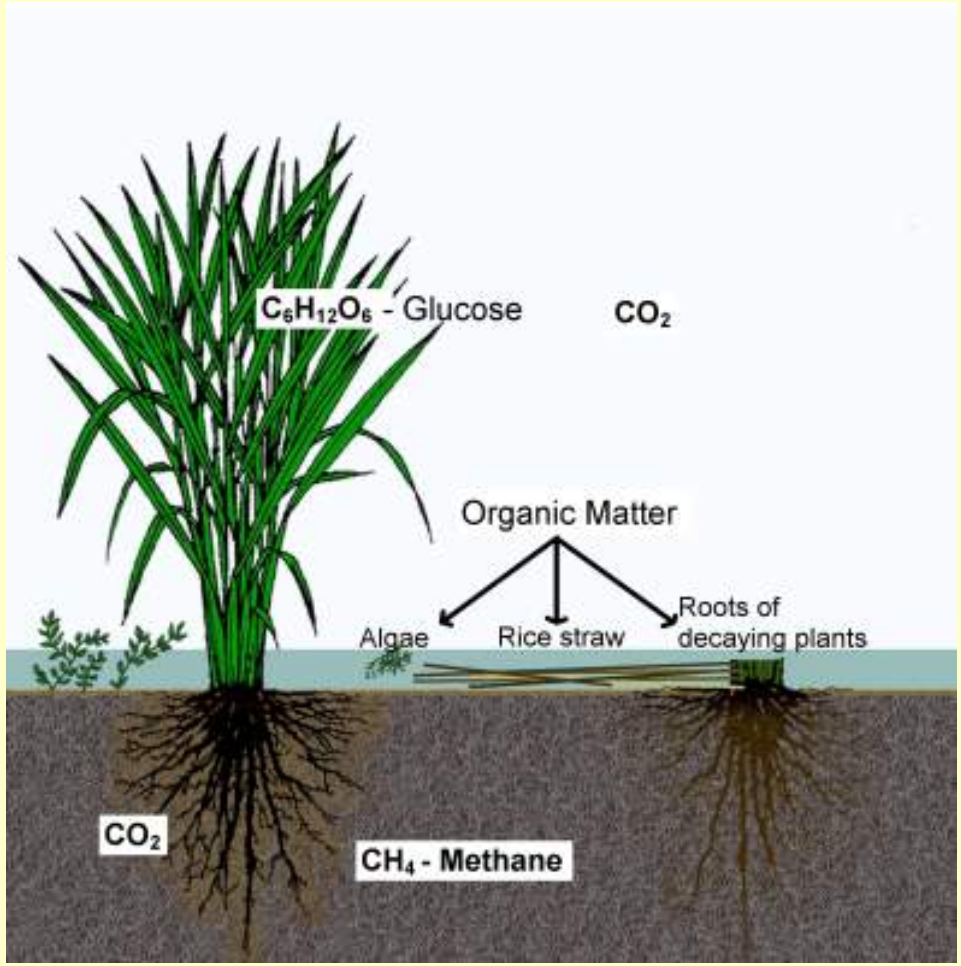
Lesson 2 - Carbon compounds in a submerged rice paddy

- C compounds in the rice plant
- Organic matter
- Carbon dioxide (CO_2)
- Methane (CH_4)



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Lesson 2 – Summary slide

- Growth of living organisms results in countless C forms
- These C forms are broken down by decomposition after the organisms die
- C compounds decompose at different rates depending on their complexity and the decomposing organisms present

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Lesson 3 – Organic matter and decomposition

- Question: What happens when organic materials are added to soil?

- Objective: Be able to describe the formation of soil organic matter

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Lesson 3 – Organic materials and organic matter

- Organic materials are plant and animal residues not yet added to soil
  - rice straw and animal manure are examples of organic materials
- Soil organic matter is organic material within soil

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Lesson 3 – Decomposition

- Once organic materials are added to soil, decomposing organisms begin digesting them
- Decomposition proceeds more quickly with:
  - warm soil temperatures
  - adequate soil moisture
  - good aeration
- C compounds remaining after decomposition become part of stable soil organic matter called humus

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Lesson 3 – Things to consider

- Soils rich in organic matter are characteristically dark in color.
- Soil organic matter contains 3-4 times as much C as is found in all the world's living vegetation.
- The mean level of organic C in the topsoil of lowland rice areas across tropical Asia is between 1-2%.

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Lesson 4 – Products of decomposition

- Question: How do the products of decomposition differ in aerobic versus anaerobic environments?

- Objective: Be able to differentiate the products of aerobic versus anaerobic decomposition.

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Lesson 4 - Decomposition in aerobic soil

In aerobic soil:

- there is a significant diversity of decomposing organisms including larger animals
- more energy is available for decomposition. Aerobic respiration results in more energy than anaerobic respiration.
- a significant portion of the digested C is released as CO_2

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Lesson 4 - Decomposition in submerged soil

In submerged soil:

- decomposition is slower
  - there are fewer decomposing organisms – mostly anaerobic bacteria
  - less energy is produced during anaerobic respiration
- products are different
  - methane (CH_4)
  - buildup of transition products like organic acids and alcohols

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Lesson 4 – Comparing products of decomposition

Element	Aerobic soil	Submerged soil
carbon (C)	Carbon dioxide (CO_2)	Carbon dioxide (CO_2) Methane (CH_4)
nitrogen (N)	Nitrate (NO_3^-)	Ammonium (NH_4^+)
sulfur (S)	Sulfate (SO_4^{2-})	hydrogen sulfide (H_2S)
others		organic acids and alcohols

The left column lists the main elements found in decomposing organic matter. The middle column shows the typical form of the element after decomposition in aerobic soil. The right column shows the element's typical form after decomposition in submerged soil.

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Lesson 4 – Why is methane significant?

- In the past few decades, CH_4 has been monitored because of its role in climate change.
- CO_2 and CH_4 both contribute to the greenhouse effect
- CH_4 is 25 times more potent than CO_2 in absorbing radiation reflected from the earth's surface over a 100 yr time period

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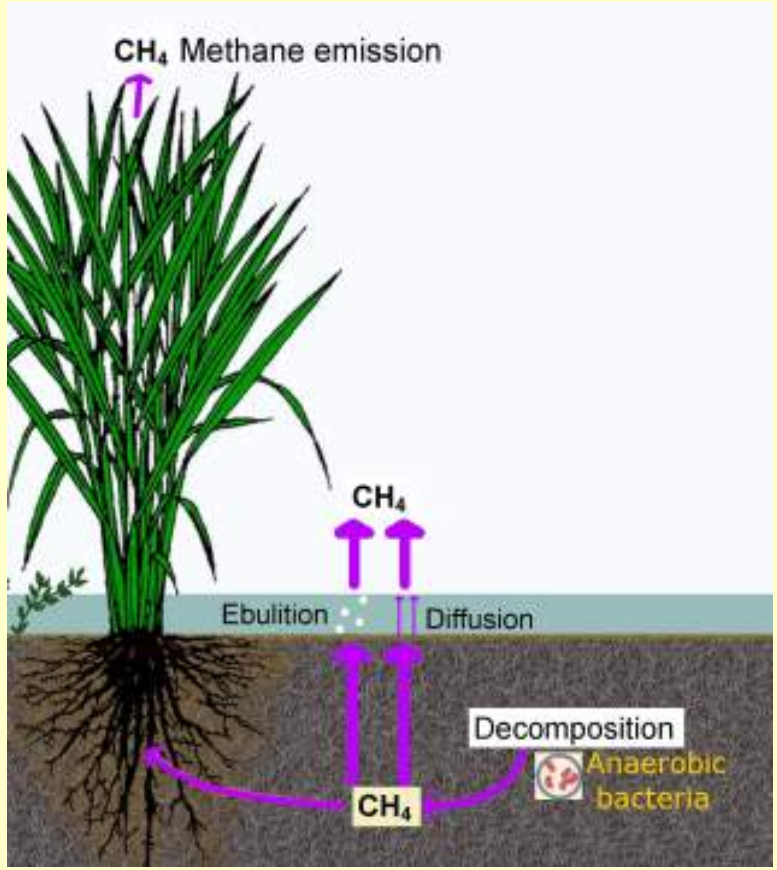
Lesson 4 – Movement of methane into the atmosphere

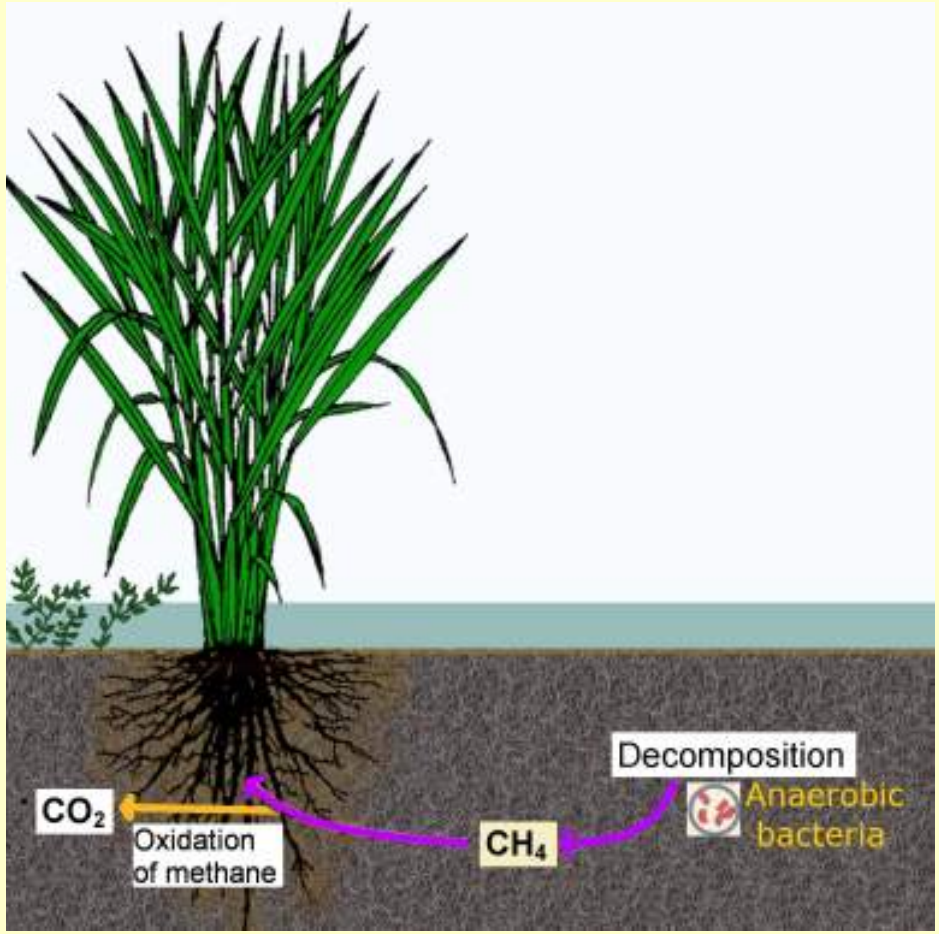
CH_4 moves from soil into the atmosphere by these processes:

- ebullition - bubbling through the soil and water layer
- diffusion - moving from areas of high to low concentration
- emission - passing through rice plant aerenchyma and out from the leaves. Most methane in the rice paddy moves from soil to atmosphere via emission.



Lesson 4 – Oxidation of methane

- 20-90% of CH_4 produced in flooded soil is oxidized to CO_2 before being released to the atmosphere.



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Lesson 4 – Summary slide

- Decomposition in submerged soil produces different products than aerobic decomposition.
- CH_4 is an important decomposition product in submerged soil.
- Both CO_2 and CH_4 contribute to climate change. CH_4 is 25 times more potent than CO_2
- Most methane emitted into the atmosphere passes through the rice plant

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Lesson 4 – Question to consider

- What practices could a farmer use to reduce the amount of CH_4 produced during rice production?
  - consider when organic materials are applied

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Lesson 5 – Adding organic materials?

- Lesson 5 - What are the advantages and disadvantages of adding organic materials?

- Objective: Be able to identify benefits of organic matter in an aerobic and anaerobic setting.

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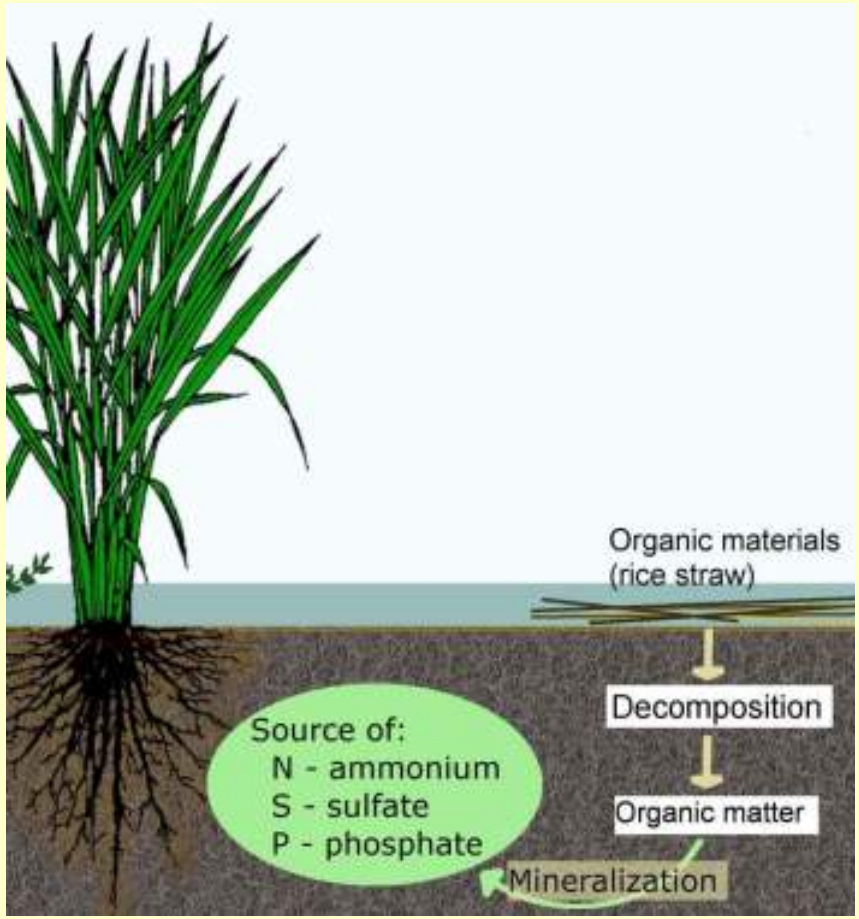
Lesson 5 - Why is organic matter important? (1)

Organic matter is a source of nutrients

- Nutrients become available to plants as compounds containing these nutrients are decomposed
- It is an important source of nitrogen, sulfur, and phosphorus



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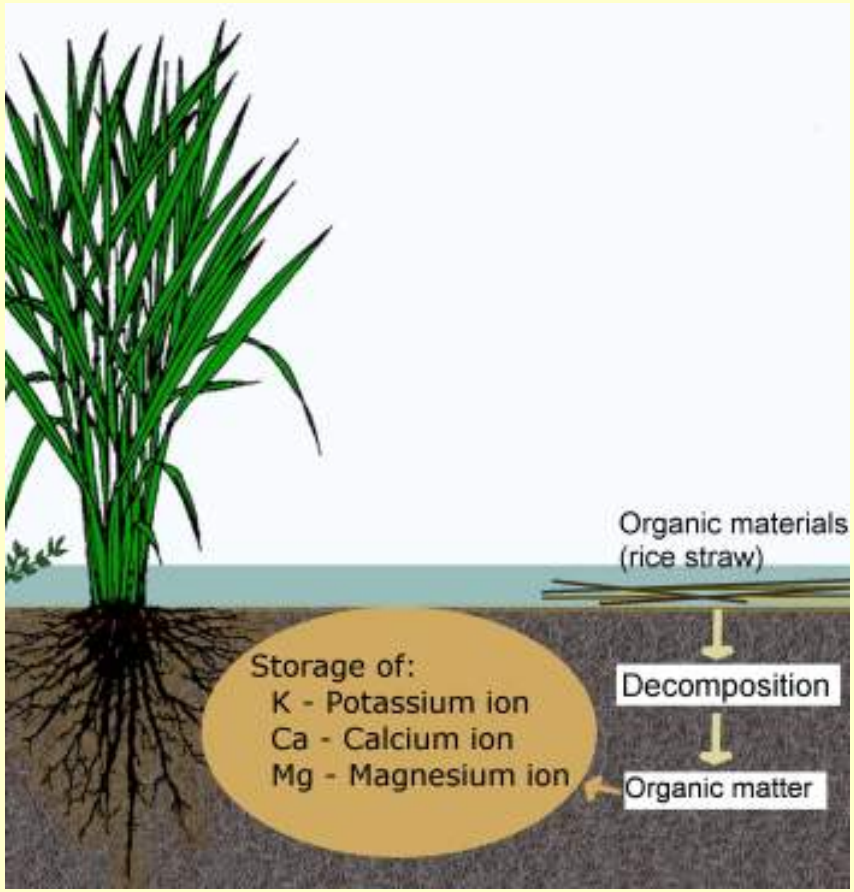
Lesson 5 - Why is organic matter important? (2)



Nutrient storage

- Organic matter attracts and 'stores' some nutrients through electrical charges
- These nutrients may otherwise be lost through leaching or fixation

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Lesson 5 - Why is organic matter important? (3)

Other important characteristics of organic matter:

- Provides food for soil organisms and microorganisms
- Binds soil particles together to form aggregates
  - Aggregates help water movement in soil
  - They aid in soil's ability to hold water
  - They reduce surface erosion from wind and water
- Encourages root development as a result of improved soil structure

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Lesson 5 - Organic matter in aerobic soil

In aerobic soil:

- Organic matter is continually oxidized and lost as CO_2
- Tillage increases the rate of organic matter decomposition
- Soil aggregates are important in aerobic soil for aeration, drainage, and water holding capacity
- Organic materials should be added to sustain the amount of organic matter in soil

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Lesson 5 - Organic matter in submerged soil

In submerged soil:

- Organic matter tends to accumulate due to slow decomposition of organic material
- It is often unnecessary to add additional organic materials to sustain organic matter levels.

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Lesson 5 – Summary points

- Organic matter is an important source of plant nutrients like nitrogen, sulfur, and phosphorus
- Organic matter attracts and stores some nutrients and then makes them available to plants
- Organic matter decomposes relatively quickly in aerobic soil
  - additional organic materials should be added to maintain the amount of organic matter
- It is often unnecessary to add additional organic materials to submerged soils due to slower decomposition

Module 3

Review Questions for Module 3

1) Circle the letter of the correct statement:
   a) Decomposition in an aerobic environment is typically faster and more complete than an anaerobic environment because of the presence of oxygen.
   b) Decomposition in an anaerobic environment is typically faster and more complete than in an aerobic environment.

2) Cellulose, sugar, and lignin are three carbon compounds found in plants.
   – Of these three, which typically decomposes fastest?
   – Which decomposes slowest?

Module 3

Review Questions for Module 3

3) Circle the letter of the correct statement below.
   a) Organic matter is important as a source of nutrients
   b) Organic matter is important for nutrient storage
   c) Organic matter quickly oxidizes in an aerobic environment so organic materials must be continuously added.
   d) Organic materials tend to accumulate in an anaerobic environment so it may not be necessary to add additional materials in order to maintain organic matter levels.
   e) All of the above

4) True or False: Methane is an important product of decomposition in submerged soil but a large portion of this methane is oxidized and becomes carbon dioxide before it enters the atmosphere.

Module 3 Review Questions for Module 3

5) Circle the letter of the incorrect statement:

a) Carbon bonds are significant for all living things.

b) Millions of compounds contain carbon

c) Carbon is the most abundant element in the universe

d) Organic matter is rich in carbon

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Answers to Review Questions

1. a) is correct (Lesson 3)
2. fastest – sugar (Lesson 2)
   slowest – lignin
3. e) is correct (Lesson 5)
4. True (Lesson 4)
5. c) Carbon is the forth most abundant element after hydrogen, helium, and oxygen. (Lesson 1)