Module 3 – Soil Science & Soil Health
Student Notes

These notes are designed to help you understand the main ideas, vocabulary, and concepts from Module 3. Each section matches the learning outcomes and activities discussed in class. Use these notes to study for quizzes, complete projects, and participate in discussions.

Note: Vocabulary words marked with an asterisk (*) are required knowledge. Unmarked words are included for enrichment.

Lesson A – Soil Fundamentals

Learning Outcomes:

- **Remember:** Define *soil health* and identify its three interacting components: physical (texture & structure), chemical (pH & nutrients), and biological (organic matter & organisms).
- **Understand:** Explain how soil texture and structure influence water movement, nutrient retention, and root growth. Recognize how pH affects nutrient availability.
- **Apply:** Conduct simple tests (Texture by Feel, pH test, infiltration) and interpret what the results reveal about soil function and sustainability.
- **Analyze:** Connect soil indicators (texture, pH, organic matter) to functions like water regulation, nutrient cycling, and ecosystem services. Map these functions to the relevant SDGs.

  Key Concepts:
  - Soil Health* – *The continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans.*
  - Soil Components – Healthy soils include ~45% mineral particles, ~25% air, ~25% water, and ~5% organic matter. That small organic matter fraction fuels microbes, stores nutrients, and improves structure.
  - Texture vs. Structure* – *Texture* refers to the relative proportions of sand, silt, and clay and sets the soil's basic "personality." *Structure* describes how particles clump into aggregates; good structure improves infiltration and root growth.
  - pH & Nutrients – pH controls nutrient availability; most nutrients are available at pH 6.0–7.0. Macronutrients include N, P, K, S, Ca, Mg. Micronutrients include Fe, Mn, Zn, Cu, B, Mo, Cl, Ni.
  - NRCS Principles – Keep soil covered, minimize disturbance, maximize biodiversity, maintain living roots, and integrate livestock (or analogues like compost/vermicompost).
  - Ecosystem Services – Healthy soils grow plants, store and filter water, cycle nutrients, support biodiversity, filter pollutants, and store carbon.
  - SDG Connections – Soil health advances SDG 2 (Zero Hunger), SDG 6 (Clean Water), SDG 12 (Responsible Consumption & Production), SDG 13 (Climate Action), SDG 15 (Life on Land), and SDG 3 (Good Health & Well-Being).

Think About:

- How do texture and structure together influence water availability and root growth? Why might a sandy soil behave differently from a clayey soil?
- What problems might arise when soil pH is too low (acidic) or too high (alkaline)? How could a farmer or gardener adjust pH using sustainable practices?
- Which of the NRCS principles do you think is easiest to apply in a home or school garden? Which might be the most challenging?

Important Vocabulary/Word Bank:

A. Soil Health*
B. Texture*
C. Structure*
D. Organic Matter*
E. pH*
F. Macronutrients

G. Micronutrients
H. Infiltration
I. NRCS Principles*
J. Ecosystem Services

Vocabulary in Context- Fill in the Blanks using Word Bank

1. _____ describes the continued capacity of soil to function as a vital living ecosystem.

2. Soil _____ refers to the proportions of sand, silt, and clay, while soil _____ refers to how particles clump into aggregates.

3. A small (~5%) fraction of _____ fuels microbes, stores water, and binds particles.

4. Soil _____ measures how acidic or alkaline soil is and controls nutrient availability.

5. Nitrogen, phosphorus, and potassium are examples of _____, while iron, manganese, and zinc are _____.

6. The _____ encourage keeping soil covered, minimizing disturbance, maximizing biodiversity, maintaining living roots, and integrating livestock.

7. Healthy soils provide multiple _____ such as plant production, water filtration, nutrient cycling, biodiversity support, pollutant buffering, and carbon storage.

Folder/cover paper here and test your knowledge

Self-Test: Fill in the Blank

1. Soil health is the continued capacity of soil to function as a living _____.

2. Healthy soil is made up of about _____% minerals, _____% air, _____% water, and _____% organic matter.

3. Soil _____ refers to the proportions of sand, silt, and clay, while soil _____ refers to how particles are arranged into aggregates.

4. Soil _____ measures acidity or alkalinity and determines the availability of nutrients.

5. Nitrogen, phosphorus, and potassium are examples of _____, while iron, manganese, and zinc are _____.

6. The _____ principles encourage keeping soil covered, minimizing disturbance, maximizing biodiversity, maintaining living roots, and integrating livestock.

7. Healthy soils provide multiple _____ such as plant growth, water filtration, nutrient cycling, and carbon storage.

Reflection Questions

- How do soil texture and structure work together to influence water movement and root growth? Give an example comparing sandy soil to clayey soil.

- What challenges arise when soil pH is too low or too high? How might farmers or gardeners adjust pH using sustainable practices?
- Of the NRCS principles, which do you think would be easiest to implement in a home or school garden, and which might be most challenging?

Lesson B – Carbon in Soils

Learning Outcomes

- **Remember:** Recall the Build–Maintain–Consume framework for soil carbon and differentiate between carbon *storage* and *sequestration*.
- **Understand:** Describe how plants pump carbon into soils, how microbes transform it, and why aggregates and mineral associations protect organic matter.
- **Apply:** Conduct soil organic matter (SOM) and respiration tests to measure carbon inputs and microbial activity. Observe compost decomposition and connect it to carbon cycling.
- **Analyze:** Propose management practices (cover crops, mulches, reduced tillage, compost/vermicompost, biochar) that build and maintain soil carbon while balancing consumption. Explain trade-offs and design context-appropriate solutions.

  Key Concepts:
  - **Build–Maintain–Consume Triad*** – A framework for managing soil carbon: *Build* carbon by adding plant residues, cover crops, compost, and living roots; *Maintain* carbon by protecting soil with aggregates, ground cover, and minimal disturbance; *Consume* carbon through microbial respiration and harvest—our job is to balance consumption so stocks increase over time.
  - **Carbon Storage vs. Sequestration*** – *Storage* is the total carbon currently in soil; *sequestration* is the net increase beyond baseline—additional CO_2 pulled from the atmosphere and kept in soil. Imported compost increases storage locally but may not sequester carbon globally unless net stocks rise.
  - **Soil Carbon Cycle** – Plants photosynthesize and send carbon belowground through roots and exudates; microbes decompose inputs, respiring some carbon and stabilizing the rest in organic matter; protection within aggregates and mineral associations prolongs carbon retention.
  - **Humus vs. Continuum** – Modern science shows that soil organic matter is a continuum of decomposing compounds rather than a single “humus” substance; persistence depends on accessibility and protection.
  - **Practices That Work** – Cover crops and longer living roots; residue return and mulches; reduced tillage; diverse rotations; compost and manure; biochar (context-specific); integration of livestock (or analogues like vermicomposting).
  - **Co-Benefits & Trade-Offs** – Building soil organic carbon increases water holding, reduces runoff, improves nutrient cycling, stabilizes yields, and supports biodiversity; trade-offs include potential N_2O emissions from over-wet soils, compaction from heavy traffic, and pest risks from certain residues.

Think About

- Why is distinguishing between carbon storage and sequestration important when evaluating soil practices? How might adding imported compost be different from growing a cover crop on site?
- Describe an instance where a practice might Build and Maintain carbon simultaneously. What trade-offs might that practice entail?
- If a farmer’s soil is low in organic matter and has weak structure, which two practices from the word bank would you recommend? Explain your reasoning.

Important Vocabulary/Word Bank:

A. Build–Maintain–Consume Triad*

B. Carbon Storage*
C. Sequestration*
D. Soil Organic Matter (SOM)
E. Respiration
F. Compost
G. Cover Crop
H. Biochar
I. Aggregates
J. Rhizosphere

Vocabulary in Context- Fill in the Blanks using Word Bank

1. The _____ framework encourages us to add diverse inputs, protect them with minimal disturbance and cover, and recognize natural decomposition.

2. _____ is the carbon currently held in soil, while _____ refers to the net increase of carbon stored beyond a baseline.

3. Leaves, roots, and plant exudates feed microbes and become _____, the pool of decomposing organic compounds in soil.

4. Microbes respire CO_2 during _____, releasing some carbon back to the atmosphere.

5. A _____ adds fresh plant growth between cash crops to build carbon and protect soil.

6. Returning food scraps to soil through _____ adds organic matter and inoculates microbes.

7. _____ is a carbon-rich amendment that can improve water holding and provide habitat for microbes.

8. Soil particles glued together into _____ create pore space for air and water.

9. The _____ is the zone around roots where plants release exudates to feed microbes.

Folder/cover paper here and test your knowledge

Self-Test: Fill in the Blank

1. The _____ framework guides soil carbon management by encouraging us to Build, Maintain, and balance Consumption.

2. Carbon _____ is the total amount of carbon currently stored in soil, while carbon _____ is the net increase beyond a baseline.

3. Plants pump carbon into the soil through roots and _____, which microbes then use as food.

4. Microbial _____ releases carbon dioxide back into the atmosphere during decomposition.

5. Adding _____ or _____ can increase soil organic matter and boost microbial activity.

6. Soil particles held together as _____ help protect organic matter from rapid decomposition.

7. _____ is a carbon-rich amendment that can improve soil water holding and provide habitat for microbes.

8. Building soil organic carbon has many co-benefits, such as improving _____ and stabilizing _____.

Reflection Questions

- Why is it important to distinguish between carbon storage and sequestration when evaluating soil practices? How could imported compost differ from a homegrown cover crop in this respect?

- Describe one practice that can both Build and Maintain soil carbon at the same time. What trade-offs might that practice bring?

- If a farmer's soil is low in organic matter and has poor structure, which two practices would you recommend to improve it? Explain why you chose them.

Lesson C – Living Soils & Ecosystem Services

Learning Outcomes

- **Remember:** Identify key soil organisms—bacteria, fungi, mycorrhizae, earthworms—and describe their roles in nutrient cycling, aggregation, and disease suppression.
- **Understand:** Explain how the rhizosphere functions as a hotspot of biological activity and how C:N balance affects decomposition and nutrient release.
- **Apply:** Perform a slake test to observe aggregate stability, an infiltration race to compare soil cover effects, and a design challenge to propose microbe-boosting practices. Use observations to infer soil function and SDG connections.
- **Analyze:** Link soil biology to ecosystem services and human health (One Health). Evaluate risks of soil degradation and propose management actions that support soil organisms and public health.

Key Concepts:

1. **Rhizosphere*** – The narrow region around plant roots where root exudates feed microbes and intense nutrient cycling occurs. Bacteria, fungi, and mycorrhizae congregate here.
2. **Soil Food Web** – An interconnected community of organisms (bacteria, fungi, earthworms, protozoa, nematodes, arthropods) that decompose organic matter, recycle nutrients, build structure, and regulate populations.
3. **Microbial Functions** – Decomposition and nutrient cycling; aggregate formation; disease suppression; production of phytohormones and symbiotic relationships; salinity regulation.
4. **C:N Ratio*** – The ratio of carbon to nitrogen in organic materials; microbes operate efficiently near 24:1. High C:N (e.g., wheat straw) decomposes slowly and may immobilize N temporarily; low C:N (e.g., legume residue) decomposes quickly.
5. **One Health*** – The concept that soil, plant, animal, and human health are interconnected. Healthy soils support nutrient-dense food, clean water, climate regulation, and disease suppression.
6. **Aggregate Stability & Infiltration Tests** – Hands-on methods to observe how soil structure influences erosion and water movement. Covered or mulched soils typically show higher stability and infiltration.
7. **Microbe Boosters** – Practices that increase biological activity, such as adding compost or vermicompost, planting diverse cover crops, reducing tillage, applying mulch, or using biochar.

Think About

- Why do plants "pay" microbes with carbon exudates? What do they get in return?
- Describe two ways soil organisms improve soil structure and two ways they suppress disease.

- How could composting food waste at school be both a microbe booster and an SDG action? Which SDGs would it support?
- In your own words, explain the One Health concept. How does soil health relate to human health and well-being?

Important Vocabulary/Word Bank:

A. Rhizosphere*
B. Soil Food Web
C. Bacteria
D. Fungi
E. Mycorrhizae*
F. Earthworms
G. C:N Ratio*
H. One Health*
I. Aggregate Stability
J. Infiltration

Vocabulary in Context- Fill in the Blanks using Word Bank

1. The _____ is the zone around roots where exudates feed microbes and intense nutrient cycling occurs.

2. A diverse _____—including bacteria, fungi, protozoa, and earthworms—decomposes organic matter, recycles nutrients, builds structure, and suppresses pests.

3. Symbiotic fungi that extend root reach and exchange nutrients for carbon are called _____.

4. _____ shred organic matter, create biopores, and mix soil, improving aeration and nutrient cycling.

5. Maintaining a balanced _____ (around 24:1) ensures efficient decomposition without tying up nitrogen.

6. The _____ concept links soil, plant, animal, and human health.

7. A _____ test reveals how well soil aggregates hold together when wetted, indicating the presence of microbial glues and organic matter.

8. A simple _____ experiment compares how quickly water enters soils under different cover treatments.

Folder/cover paper here and test your knowledge

Self-Test: Fill in the Blank

1. The _____ is the zone around roots where plants release exudates that feed microbes and drive nutrient cycling.

2. The interconnected community of bacteria, fungi, protozoa, nematodes, and earthworms is called the _____.

3. Symbiotic fungi that extend plant root systems and trade nutrients for carbon are known as _____.

4. _____ are soil organisms that shred organic matter, create biopores, and mix soil to improve aeration.

5. A balanced _____ ratio of around 24:1 allows microbes to decompose organic matter efficiently.

6. The _____ concept connects soil health to the health of plants, animals, and people.

7. A _____ test shows how well soil aggregates hold together when wetted, reflecting biological activity.

8. An _____ experiment compares how quickly water enters soils with different covers.

Reflection Questions

- Why do plants “pay” microbes with carbon-rich exudates? What benefits do they receive in return?
- Describe two ways that soil organisms improve soil structure and two ways they help suppress disease.
- How could composting food waste at school act as both a microbe booster and an SDG action? Which specific SDGs would it support?
- In your own words, explain the One Health concept. How does improving soil health also improve human health and community well-being?

These notes are intended as a study guide and in-class reference. Use the Word Bank to fill in the blanks, answer the reflection questions, and test yourself before exams or activities. Be curious—healthy soils are the foundation for healthy people and a healthy planet!