Module 3: Soil Science and Soil Health
Instructor Guide

Module Overview
Soil is the living foundation of agriculture and a keystone of ecosystem health. This module introduces students to soil science through three dimensions: physical properties (texture, structure, pH, nutrients), carbon dynamics (Build–Maintain–Consume triad, carbon storage vs. sequestration), and biological activity (soil organisms and ecosystem services). Students engage in field and lab tests, connect results to global sustainability goals, and design soil-health improvement practices for their school or community.

Healthy soils are shown not only as essential for food production but also for clean water, biodiversity, and climate regulation — reinforcing circular economy and agroecology principles from Modules 1–2.

Materials Provided
- Presentation Slides: Module 3 deck with diagrams, visuals, SDG links.
- Student Worksheets/Guided Notes: Warm-ups, lab data tables, reflection prompts.
- Lab Materials:
    - Soil samples (garden, field, or community sources)
    - NRCS texture-by-feel guides
    - Soil pH strips/kits and optional N-P-K test kits
    - Infiltration test rings (or plastic bottles), water, stopwatch
    - Bulk density cylinders (optional alternative)
    - Soil respiration jars or probes, compost/vermicompost samples
    - Materials for slake test (aggregate stability)
- Basic PPE: Gloves, safety glasses if using reagents.

What Should Students Walk Away With
By the end of Module 3, students should be able to:
- Define soil health as the continued capacity of soil to function as a vital living ecosystem.
- Identify and measure key soil health indicators (texture, pH, organic matter, respiration, biological activity).
- Explain the soil carbon cycle and apply the Build–Maintain–Consume framework.
- Recognize the role of soil organisms in nutrient cycling, aggregation, and disease suppression.
- Recommend a management practice (e.g., cover crops, compost, reduced tillage) that improves soil health and links to an ecosystem service.
- Connect local soil practices to global SDGs (Zero Hunger, Clean Water, Climate Action, Life on Land).

Key Question:
How can we measure and improve soil health so that farms are more productive, climate-resilient, and circular?

Essential Questions:
- How do we improve soil health so that it functions as a vital living ecosystem that sustains plants, animals, and humans?
- How does carbon enter, stay in, and leave soil—and how can we tip the balance to build SOM and resilience?
- How do living soil organisms build structure, cycle nutrients, and suppress disease—and how can we manage them to deliver clean water, climate resilience, and healthy crops?

Lesson A: Soil Basics & Functions

Summary: Students explore the physical and chemical foundations of soil. Using NRCS methods, they test soil texture (sand, silt, clay), pH, and infiltration. They discover why even ~5% organic matter has an outsized role in fertility and water retention. The lesson reframes soil as a living system with multiple functions: regulating water, cycling nutrients, filtering pollutants, providing stability, and sustaining life.
Focus: Components of soil, texture/structure, nutrients, pH, and why SOM is critical.
Slides: 3-24

Lecture Notes:

- Warm-Up Discussion: "How do we improve soil health so that it functions as a vital living ecosystem that sustains plants, animals, and humans?"
- Lecture-class Interaction slide: What Is Soil?
- The NRCS core definition of soil health and why it matters:
- Explain the differences between soil and dirt:
- Poll Question: "What is soil?": Students will jot down 3 words they think of with "soil"
- Texture and structure of soil and how it behaves (fixed and changeable traits)
- What makes soil "healthy"?: Explain soil as a vital living ecosystem with many benefits and functions
- Nutrients 101: Macro vs. Micro & Why pH Matters: Explain the ideal pH level for soil and the functions of microbes in soil
- Minimize Disturbance: Explain how disturbing soil less leads to greater benefits and fewer consequences
- Maximize Biodiversity: Diversity above ground leads to diversity below ground
- Soil Health = Ecosystem Services (Beyond Yield): The better the soil health, the more benefits and services the ecosystem can provide, and the better it can thrive
- Link Back to Modules 1-2 & the SDGs

Student Activities (Optional):

- soil infiltration
  - Watch the video with your students, and students will time how long water infiltrates different soils in real-time while watching it

Key Vocabulary:

- Soil texture, soil structure, organic matter, pH, macro-nutrients, infiltration.

Objectives:

- **Define** soil health using the NRCS definition and list the five soil functions.
- **Classify** a soil by texture using the NRCS Texture-by-Feel method and infer likely drainage/root aeration.
- **Measure** soil pH with an NRCS quick test and interpret one nutrient-availability implication; propose one pH-nudging practice.
- **Map** each measured property (texture/structure, pH, optional infiltration/bulk density) to at least one SDG (2, 6, 13, 15) and justify the link in one sentence.

Lesson B: Soil Carbon & Management

Summary: Lesson B explores how we can redesign food production systems. Students compare the conventional "linear" agricultural paradigm (take–make–waste) with circular economy models and agroecological principles. They learn that the agri-food sector is currently one of the greatest waste-producing sectors, with significant losses and by-products at every stage (aimspress.com). Circular economy thinking – reducing waste, reusing biomass, recycling nutrients and energy – is presented as a valid solution to make agriculture more sustainable (aimspress.com). Students discover real examples of waste valorization pathways: composting and anaerobic digestion turn food scraps to fertilizer and energy; innovations like insect farming or biochar production convert waste into animal feed or soil amendments. They also discuss agroecology, which applies ecological principles to farming (e.g. nutrient cycling, biodiversity) to create regenerative systems. Through a hands-on brainstorm, students identify wastes in their school or community and propose creative "waste-to-resource" ideas – reinforcing that resources can be looped back instead of lost.
Focus: Moving from wasteful linear systems to regenerative circular models.
Slides: 25-49

Lecture Notes:

- Warm-Up Discussion: “How does carbon enter, stay in, and leave soil—and how can we tip the balance to build SOM and resilience?”
- Carbon In, Carbon Out, Carbon Kept: To build plant inputs, maintain carbon in aggregates and on minerals, and consume through microbial respiration
- The Soil-Carbon Cycle: Plants create inputs which are transformed by microbes, and throughout the process some carbon is respired, some stabilized as soil organic matter (SOM)
- From “Magic Humus” to a Continuum (What Stays, What Goes): Traditional vs. new view of Humus
- The Build-Maintain-Consume Triad (How We Steer It): The cycle of how carbon should be created, maintained, and used
- Bottom Line: When Do We Sequester: Sequester when build > consume long enough
- Practices That Work (Field-Proven & School-Friendly):
- Co-Benefits & Trade-Offs (Design Matters): More SOM = More resilience
- Quick Round: Place the Practice (Interactive): A one-minute challenge on where students will place each practice of compost, no-till, cover crops, and turning compost pile in the triad of build, maintain and consume

Student Activities (Optional):

- Make a compost cake (Think-Pair-Share):
    - coloring activity (the layering etc to decomposition):

Key Vocabulary:

- Soil organic matter (SOM), carbon storage, carbon sequestration, respiration, Build–Maintain–Consume.

Objectives:

- **Diagram** the soil-carbon cycle and distinguish storage (stock) vs. sequestration (rate) in correct units.
- **Categorize** practices with the Build–Maintain–Consume triad and justify placement with one mechanism.
- **Analyze** class SOM field-test and respiration data to infer the likely direction of carbon-stock change and predict water-holding effects.
- **Recommend** a two-practice bundle that increases sequestration and tag the relevant SDGs (2, 6, 12, 13, 15), stating the expected change in one indicator (e.g., infiltration ↑).

Optional Extended Learning: Carbon Accounting in Action

Extended Learning:

- Facilitate a warm-up discussion using a “Big Picture: Soil Carbon & Climate Connection” slide. Ask students: How do small soil management changes scale up to affect global carbon and climate?
- Present lecture slides covering the following topics in sequence:
    - Introduce the global carbon cycle and soil as the largest terrestrial carbon pool.
    - Explain storage vs. sequestration: stock (t C/ha) vs. net annual increase (Δ t C/ha/yr).
    - Describe the Build–Maintain–Consume framework:
        - Build: roots, residues, compost, cover crops
        - Maintain: reduced tillage, mulching
        - Consume: erosion, microbial respiration, harvest removal
    - Show positive and negative feedback loops: repeated tillage vs. cover crops and no-till.
    - Discuss real-world applications: carbon markets, Australia’s Carbon Farming Initiative, and trade-offs (compost relocation vs. net sequestration).
    - Introduce carbon accounting metrics: SOM %, respiration rate, infiltration; emission factors; and their role in measuring soil health and carbon outcomes.
    - Present technical modeling of soil carbon: how root exudates feed microbes, driving SOM formation or CO_2 release.

Optional Extended Learning Activity Corner:

- Guide students through the Carbon Detective Lab Activity:
    - Provide mini-datasets (SOM %, respiration rate, infiltration).
    - Tasks: Identify soils gaining or losing carbon, propose a 2-practice bundle (Build + Maintain), predict indicator shifts (infiltration ↑, respiration ↓), map practices to SDGs 2,

        6, 12, 13, 15.
    - Students present findings in a short “carbon action plan” memo.

Career Pathways:

- Introduces students to careers in:
    - Environmental science, soil science, and agronomy
    - Climate and sustainability consulting
    - Carbon markets and policy
    - Agricultural technology and regenerative farming
- Highlights the intersection of science, technology, and policy in solving real-world carbon and climate challenges.

Lesson C: Living Soils & Ecosystem Services

Summary: Lesson C empowers students with what actions can drive sustainable change. It frames solutions across four domains (“4 Ps”) – Planet, People, Profit, Policy, echoing research that a holistic 4-P approach is needed for food system sustainability (mdpi.com). Students first examine personal and cultural choices (“People/Planet”) by looking at diets: for instance, they calculate the carbon footprint difference between a meat-heavy meal (beef) and a plant-rich alternative (beans), seeing how a simple diet swap can cut emissions. Next, they explore innovations and entrepreneurship (“Profit”) that add sustainability to the food system: from plant-based proteins to farming tech that reduces waste. They might analyze start-up caselets or technological solutions (e.g. food waste apps, novel recycling tech) and consider how businesses can profit while being eco-friendly. Then, students consider the role of public policy (“Policy”): through a gallery walk of policy ideas (like school composting programs, incentives for sustainable farming, or laws reducing food waste), they see how government and community initiatives enable circular, sustainable practices. Finally, students are prompted to envision their own role: each sketches or pitches an action loop they can influence – whether a personal habit change, a community project, or an advocacy idea – reinforcing that multi-level action is needed for food system transformation.
Focus: Pathways to action through innovation, policy, and behavior
Slides: 50-72

Lecture Notes:

- Warm-Up Discussion: “How do living soil organisms build structure, cycle nutrients, and suppress disease—and how can we manage them to deliver clean water, climate resilience, and healthy crops?”
- The Rhizosphere: Where the Action Is: Explain roots, bacteria and fungi, fungal glues (glomalin), mycorrhizae, and earthworms
- Soil Microbes: Many Jobs, One Ecosystem: Microbes break down residues and release nutrients, and provide many beneficial functions as well
- Microbe Functions: Decomposition & Nutrient Cycling: Breakdown crew, release of nutrients, and steady supply of nutrients to prevent losses and keep roots fed
- Carbon:Nitrogen Balance in Soils (C:N Ratio): Microbes thrive around 24:1 C:N ratio → too much N can cause rapid breakdown and carbon loss, and too little N can cause slow nutrient release
- Balancing C:N: Practices and Microbes:
- Microbe Functions:
- One Health: Soil ↔ People ↔ Planet: All of these factors work in tandem together to create safe food, water, and climate resilience

Student Activities (Optional):

- Design minute - microbe boosters (Think-Pair-Share):

Key Vocabulary:

- Rhizosphere, soil food web, aggregate stability, decomposition, carbon-to-nitrogen ratio, ecosystem services.99ii

Objectives:

- **Describe** roles of bacteria, fungi (incl. mycorrhizae), and earthworms in nutrient cycling, aggregate formation, and disease suppression.
- **Evaluate** aggregate stability/slake and infiltration results to infer impacts on ecosystem services (erosion control, water quality).

- **Design** a “microbe-booster” practice for the school garden and defend it with class data; predict one SDG outcome (e.g., runoff clarity → SDG 6).
- **Compose** a 1-page, SDG-tagged recommendation memo that applies the Build–Maintain–Consume logic to campus management.

Hands-On Labs (Optional, 45 min–90 min):

- Our Soil pH Investigation (Hands-On Activity):
  - Students work in small groups to test and compare the acidity or alkalinity of soils collected from different locations.
- Our Soil Organic Matter Investigation (Hands-On Activity):
  - Students work in small groups to explore how soil organic matter (SOM) supports soil health and plant growth.
- Our Soil Stability & Respiration Investigation (Hands-On Activity):
  - Students work in small groups to compare how soils hold together and how actively they “breathe.” These tests highlight the importance of fungi and microbes in living soils.

Assessment & Wrap-Up:

- Use the student worksheet (think-pair-share) to guide notetaking, exit tickets, and small-group review
- Use review questions at the end of each lesson for formative checks

Teaching Tips:

- You do not need to cover all activities or notes—adapt to your students and your schedule
- Use the speaker notes to guide flow, but feel free to personalize delivery
- Vocabulary and mind map can be used as review tools or built upon throughout the module

Recommended Duration:

Approximately 3–5 class periods (45–55 minutes each). Lessons A, B, and C can be completed in one class period, with two-three additional periods suggested for hands-on lab activities or extension projects. The module’s timeline is flexible: educators may extend the design project or include the optional labs described below to deepen inquiry and real-world skill development.

Recommendations for Instruction:

- **Begin with relevance:** Connect the module to prior knowledge or local context. For example, ask students about food waste they see in the cafeteria or their homes as a segue into sustainability issues.
- **Reinforce systems thinking:** Emphasize links between topics – e.g. how changing diets (Lesson C) can alleviate pressure on planetary boundaries (Lesson A), or how circular strategies (Lesson B) address problems introduced earlier. Encourage students to see the food system as an interconnected web.
- **Use interactive tools:** Incorporate the student **“Food-Print” worksheet/log and vocabulary list** provided to reinforce major themes. Visual aids like a planetary boundaries chart or an SDG wheel can help students grasp abstract concepts.
- **Encourage local observation:** Have students apply concepts to familiar settings. For instance, identify a local food waste issue and brainstorm solutions (to ground Lesson B ideas), or discuss which SDGs a nearby community garden might advance.
- **Differentiate as needed:** All suggested activities are flexible. Depending on time and class level, you may shorten lectures and spend more time on discussions or vice versa. Each lesson offers at least one hands-on or minds-on “mini activity” to keep students engaged. Feel free to extend these or add your own to deepen learning.
- **Sustain positivity:** While addressing serious challenges, keep the tone hopeful by highlighting solutions and success stories. This first module should inspire students and combat the notion that “sustainability” is just about sacrifice; it’s about smart improvements and opportunities for innovation.

Need Support?

Contact the curriculum team:

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