



Module 3: Soil Science & Soil Health

Grade 11-12 Agricultural Science Lesson Plan: Foundations of Sustainable Agri-Food Systems & Circular Economy

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Module 3: Soil Science & Soil Health

Grade 11-12 Agricultural Science Lesson Plan: Foundations of Sustainable Agri-Food Systems & Circular Economy

Grade: 11-12	Subject: Agricultural Science / Environmental Science (CTE Pathway)	Topic: Soil Science & Soil Health Sub-topic: Lesson A – Soil Fundamentals; Lesson B – Carbon in Soils; Lesson C – Living Soils & Ecosystem Services (plus optional extended labs)	Lesson: Multi-day Unit (Lessons A-C + Activity Corners / Worksheets)
<p>Key Question to be Addressed in the Module: How can we measure and improve soil health to make farms more productive, climate-resilient, and circular?</p> <p>Sub-questions:</p> <ul style="list-style-type: none"> ● 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? 			
Time (lesson length): 3–4 class periods (45–55 minutes each)	Class size: 25-30 students	Resources: Wi-Fi, projector, PC, whiteboard, markers, presentation slides, printed student-guided notes, student activity worksheets, materials for design activities (poster boards, graph paper, rulers, colored pencils)	
<p>Objectives and Outcomes: At the end of this module, students should be able to:</p> <ul style="list-style-type: none"> ● Identify and measure key soil health indicators – including physical properties (soil texture and structure), chemical properties (pH and basic nutrient levels via N-P-K tests), and biological indicators (soil organic matter field tests, simple soil respiration rates, and observable soil life). ● Explain the soil carbon cycle using the Build–Maintain–Consume framework, and distinguish in simple terms between carbon storage in soil versus carbon sequestration (net removal of CO₂ from the atmosphere into soil). ● Describe how soil organisms (bacteria, fungi, earthworms, etc.) contribute to soil health by cycling nutrients, building soil structure (aggregates), and suppressing pests/diseases – linking soil biology to services like clean water and climate regulation. ● Propose a specific soil management practice (e.g., planting cover crops, adding mulch or compost, reducing tillage, starting a vermicompost, or adding biochar) that would improve a chosen soil health indicator, and explain how it would enhance at least one ecosystem service, using evidence or data from class experiments to support the recommendation. ● Connect soil health practices to broader sustainability goals by mapping their recommended practice to relevant SDGs (2, 6, 12, 13, 15) and explaining how this local action contributes to those global goals, using class data or observations as justification. 			

Breakdown

Lesson A – Soil Basics & Functions

- **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

- **Diagram** the soil-carbon cycle and distinguish between storage (stock) and sequestration (rate) in the 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 ↑).

Lesson C – Living Soils & Ecosystem Services

- **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.

The Methods and Sequence of Activities

Day 1: Lesson A - Soil Basics & Functions

Teacher Activities:

Introduction

- 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?

Student Activities:

- Participate in discussion and brainstorming
- Watch slide/video presentation and take guided notes
- Engage in activity corner(s)
- Apply lecture content to exit

Duration of Activities:

Introduction - 15 minutes
Activity Corner - 20 minutes
Closure - 10 minutes
Total - 50 minutes

<ul style="list-style-type: none"> ○ Quick poll → jot three words you think of with “soil” ● Lecture Slides: <ul style="list-style-type: none"> ○ The NRCS core definition of soil health and why it matters: <ul style="list-style-type: none"> ■ Regulate water, cycle nutrients, filter / buffer pollutants, provide stability, sustain life ■ Linking to SDGs 2, 6, 12, 13, and 15 ○ Explain the differences between soil and dirt: <ul style="list-style-type: none"> ■ Soil = Structure + pores + air + water + life ■ Dirt = Soil out of place (i.e., on floors/shoes) ○ Poll Question: “What is soil?”: Students will jot down three words they think of with “soil” ○ Texture and structure of soil and how it behaves (fixed and changeable traits) <ul style="list-style-type: none"> ■ Think-Pair-Share Prompt: Where might sand help? Where might clay help? ○ What makes soil “healthy”?: Explain soil as a vital living ecosystem with many benefits and functions <ul style="list-style-type: none"> ■ Systems view + NRCS principles ○ Nutrients 101: Macro vs. Micro & Why pH Matters: Explain the ideal pH level for soil and the functions of microbes in soil <ul style="list-style-type: none"> ■ Think-Pair-Share Prompt: pH 5.2; likely issues? One non-dumping practice to nudge toward neutral pH? ○ Minimize Disturbance: Explain how disturbing soil less leads to greater benefits and fewer consequences 	<p style="text-align: center;">ticket questions</p>	
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- 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

Activity Corner

- Soil Infiltration (Think-Pair-Share):
 - Students test how soil structure and practices affect water infiltration
 - You will:
 - Spot one factor that improves vs. reduces infiltration
 - Propose a practice to increase infiltration
 - Link it to a soil function + SDG

Closure

- Exit Ticket:
 - Exit Ticket: Students answer in 2–3 sentences: Which practices seem easiest to apply in a school garden? Which practices would be hardest to scale on a large farm?

Materials

- Excerpt/diagram from NRCS “Soil Infiltration” PDF
- Access to the two short YouTube explainers (or teacher summary if no internet)
- Student notebooks or worksheet copy

Student Assessment: Student understanding will be assessed through a required quiz covering key concepts from the lesson. The quiz will evaluate how accurately students 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. Optional activities, such as the “Food-Print Snapshot,” will serve as enrichment and are not graded.

Day 2: Lesson B - Soil Carbon & Management

Teacher Activities:

Introduction

- Warm-Up Discussion: “How does carbon enter, stay in, and leave soil—and how can we tip the balance to build SOM and resilience?”
- Lecture Slides:
 - 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)
 - Storage vs. Sequestration: How much carbon is in the soil now vs. increase in carbon stock per year
 - Why It Matters: When building carbon > consuming carbon, carbon stocks rise (link to SDG 13 - Climate Action)
 - 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):
 - Maximize continuous living roots

Student Activities:

- Participate in discussion and brainstorming
- Watch slide / video presentation and take guided notes
- Engage in activity corner(s)
- Apply lecture content to exit ticket questions

Duration of Activities:

Introduction - 15 minutes
Activity Corner - 25 minutes
Closure - 10 minutes
Total - 50 minutes

- Maximize biodiversity
 - Minimize disturbance
 - Maximize soil cover
- Co-Benefits & Trade-Offs (Design Matters):
More SOM = More resilience
 - Design Matters: Over-wet soils can boost N₂O emissions, and adaptive management is required to test, observe, and adjust
 - Think-Pair-Share Prompt: Is purchased compost sequestration or storage – and why?
- 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

Activity Corner

- Make a Compost Cake (Think-Pair-Share):
 - Students model how decomposition drives soil carbon cycling
 - You will:
 - Color & label compost cake layers (browns, greens, soil, water)
 - Add arrows for carbon and nutrient flows
 - Redesign your cake for a goal: carbon storage or fast nutrient release

Closure

- Exit Ticket:
 - Each student writes down one example action for each triad step (Build, Maintain, Consume) and names one specific practice to increase soil carbon sequestration. They

<p>should indicate which soil health indicator that practice would improve (e.g., cover crops → increased infiltration rate) and which SDG it contributes to.</p> <p>Materials</p> <ul style="list-style-type: none"> • Presentation slides, student-guided notes, student activity worksheets 		
<p>Student Assessment: Student understanding will be assessed through a required quiz covering key concepts from the lesson. The quiz will evaluate how accurately students 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, and Analyze class SOM field-test and respiration data to infer the likely direction of carbon-stock change and predict water-holding effects. Optional activities, such as the “Food-Print Snapshot,” will serve as enrichment and are not graded.</p>		
<p>Day 3: Lesson C - Living Soils & Ecosystem Services</p>		
<p>Teacher Activities:</p> <p><u>Introduction</u></p> <ul style="list-style-type: none"> • 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?” • Lecture Slides: <ul style="list-style-type: none"> ○ 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 	<p>Student Activities:</p> <ul style="list-style-type: none"> • Participate in discussion and brainstorming • Watch slide / video presentation and take guided notes • Engage in activity corner(s) • Apply lecture content to exit ticket questions 	<p>Duration of Activities:</p> <p>Introduction - 15 minutes Activity Corner - 25 minutes Closure - 10 minutes Total - 50 minutes</p>

- 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:
 - Low-C inputs: legumes add N quickly
 - High-C inputs: grasses or high-C stover feed fungi & build glues
 - Cover-crop blends: adjust C:N, support microbial diversity
 - Think-Pair-Share Prompt: Which choice will raise the C:N of residues more at termination?
- Microbe Functions:
 - Structure & Aggregation: Certain microbes exude sticky compounds that cause aggr increases air and water flow
 - Disease Suppression: Antimicrobials produced by beneficial microbes prey on pathogens and compete for resources (e.g. trichoderma vs. pathogenic fungi)
 - Phytohormones & Symbioses: Hormones produced by microbes can encourage root growth, slow aging, and increased stress tolerance
 - Salinity Regulation: Some microbes exclude excess salt / convert salts into less harmful forms to help plants cope in salty soils
- One Health: Soil ↔ People ↔ Planet: All of these factors work in tandem together to

create safe food, water, and climate resilience

- How Healthy Soils Protect People: Filtering and storing water through stable aggregates, moderation of climate by building soil organic carbon, soil microbiome suppressing diseases and helping to detoxify pollutants
- Risks & Responses: Intensive and poorly managed systems can degrade soil, and stewardship restores biodiversity and function through diagnosing issues and treating them

Activity Corner

- Design Minute - Microbe Boosters (Think-Pair-Share):
 - Students model how soil management practices boost microbes and soil health
 - You will:
 - Pick one practice (cover, compost, mulch, till, vermi, biochar)
 - Predict its effect on a soil indicator
 - Link to an ecosystem service + SDG
 - Sketch and defend your design

Closure

- Exit Ticket:
 - Students individually list two ways that soil organisms help plants or soil health (e.g., “bacteria break down organic matter into nutrients,” “mycorrhizae increase plants’ nutrient access”) and one action our school/community could take to support those organisms (for example, start a

<p>compost program or plant a cover crop), along with which SDG that action relates to.</p> <ul style="list-style-type: none"> • Module 3 Key Takeaways and Mindmap • Career Pathways • Sneak Peak of Hands-On Activities <p><u>Materials</u></p> <ul style="list-style-type: none"> • Presentation slides, student-guided notes, student activity worksheets 		
<p>Student Assessment: Student understanding will be assessed through a required quiz covering key concepts from the lesson. The quiz will evaluate how accurately students 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), and learn how to 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). Optional activities, such as the “Make a compost cake”(Think-Pair-Share) will serve as enrichment and are not graded.</p>		
<p>Day 4 / Day 5 - Hands-On Activity: Our Micro Farm</p>		
<p>Teacher Activities:</p> <ul style="list-style-type: none"> • Soil pH (Hands-On Activity): <ul style="list-style-type: none"> ○ Students work in small groups to test and compare the acidity or alkalinity of soils collected from different locations. ○ They will: <ul style="list-style-type: none"> ■ Collect soil from at least three locations (garden bed, lawn, forest edge, or potted soil) at a shallow depth (2–4 inches). ■ Prepare three replicate soil–water slurries for each location. ■ Use pH strips to measure the pH of each slurry and record the values. ■ Calculate the average pH for each location and classify soils as acidic, neutral, or alkaline. 	<p>Student Activities:</p> <ul style="list-style-type: none"> • Participate in hands-on activities and data collection / analysis 	<p>Duration of Activities:</p> <p>Travel - 0 minutes (within school compounds)</p> <p>Activity Corner - 1 day for hands-on build, 1 day for data collection, 5-15 minutes across the week for ongoing check-ins</p>

- Compare results across sites to identify patterns in soil pH.
 - Reflect on how soil pH influences nutrient availability and plant growth, and suggest how gardeners or farmers might adjust soils for better productivity.
- Soil Organic Matter (Hands-On Activity):
 - Students work in small groups to explore how soil organic matter (SOM) supports soil health and plant growth.
 - They will:
 - Collect ~10 sub-samples of soil from two locations, mix them, and prepare two representative samples.
 - Use a soil color chart to estimate the % SOM in each sample.
 - Record their estimates and compare the SOM content between Sample A and Sample B.
 - Discuss how SOM influences nutrient supply, water-holding capacity, soil structure, and carbon storage.
 - Identify one land management practice that could increase SOM (e.g., cover crops) and one that could decrease SOM (e.g., intensive tillage).
- Soil Glue & Respiration (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.
 - They will:
 - Perform the Soil Glue Test by gently lowering soil clods into water to see

<p>whether they remain stable or break apart, revealing soil's physical resilience.</p> <ul style="list-style-type: none"> ■ Conduct the Respiration Reveal by combining baking soda and vinegar to capture CO₂, using fizzing intensity as a visual indicator of microbial activity. ■ Record which soil samples stayed intact and which produced stronger fizz. ■ Discuss how soil structure and microbial respiration connect to soil health. ■ Identify one management practice that can improve soil stability (e.g., no-till, cover crops) and one that can boost biological activity (e.g., compost addition). 		
<p>Student Assessment: Student understanding will be assessed through their completed data sheets and group outputs from the Soil pH Investigation, Soil Organic Matter Estimation, and Soil Stability & Respiration activities. Worksheets will be graded using a rubric that evaluates accuracy and completeness of recorded measurements (pH trials and averages, SOM color chart estimates, soil clod stability, and respiration fizz intensity), correct graphing and interpretation of results, and clarity of written notes on soil descriptions and observations. Students will also be assessed on their ability to interpret their results by comparing across soil locations and conditions, categorizing soils (acidic/neutral/alkaline, high vs. low SOM, stable vs. unstable), and linking findings to soil health principles such as nutrient availability, water retention, aggregation, microbial activity, and carbon storage. Optional extensions, such as creating bar graphs of results or proposing soil management practices to improve health indicators, will serve as enrichment and are not graded.</p>		
<p>Day 5 (Optional) Lesson B - Optional Extended Learning (OEL) – Carbon Accounting in Action</p>		
<p>Teacher Activities: <u>Introduction</u></p> <ul style="list-style-type: none"> ● Warm-Up Discussion: 	<p>Student Activities:</p> <ul style="list-style-type: none"> ● Participate in warm-up discussion and take guided notes ● Engage with lecture slides and 	<p>Duration of Activities: Introduction - 15 minutes Activity Corner - 25 minutes Closure: 10 minutes Total - 50 minutes</p>

- Facilitate a short conversation using the “Big Picture: Soil Carbon & Climate Connection” slide.
- Ask: “How do small soil management changes scale up to affect carbon storage and climate outcomes?”

- Lecture Slides:

- Big Picture: Soil Carbon & Climate Connection
- Storage vs. Sequestration
- Soil Carbon Flows & Feedbacks
- Real-World Applications & Trade-Offs
- Deeper Scientific Insights
- Carbon Detective Lab: Data-Driven Decisions
- Discussion Questions

Activity Corner

- Carbon Detective Lab Extension Optional Extended Learning Activity:
 - apply soil carbon concepts by analyzing simple datasets.
 - Students will practice distinguishing carbon storage vs. sequestration, classify practices with the Build–Maintain–Consume triad, and design a “carbon action plan” that maps soil practices to ecosystem services and SDGs.

Closure

- Reflection Questions:
 - How does analyzing real data change the way you think about soil carbon and climate action?
 - Which practice would you adopt first if you were managing a farm — compost, cover crops, or no-till — and why?
 - How do you know whether compost addition is “storage” or true “sequestration”?

- case study discussion
- Share group findings in class closure discussion and reflect on key questions

- What's one way soil carbon practices at a school garden could connect to climate action at global scale?

Materials

- Presentation slides, student-guided notes, system-mapping worksheets, colored pencils or sticky notes for mind-mapping

Student Assessment: TBD