Optional Extended Learning (OEL) – Carbon Accounting in Action

Differentiated Content

Option 1, broader. This lecture introduces carbon in soil as part of the global carbon cycle. Students learn how small soil changes scale up to climate action. NGSS focus: human impact on Earth systems, carbon cycling, and ecosystem resilience.

Option 2, more specific. This lecture deepens understanding of soil carbon and biology. Students dive into carbon accounting. They compare "storage" vs. "sequestration" with real emission factors, analyze data from soil respiration/infiltration labs, and calculate which management practices tip the carbon balance. NGSS links include:

- HS-LS2-5 (cycling of matter)
- ESS3.C (human impacts)
- SEP (Analyzing and interpreting data).

Option 1: What Is Systems Thinking? How Do We Already Use It?

Overview of Metabolic Modeling

This module positions soil as the foundation of sustainable food systems. Students extend their learning through hands-on labs, soil improvement planning, and systems-thinking applications that connect soil health to climate resilience, biodiversity, and circular agriculture.

Key Concepts:

- **Storage vs. Sequestration:** Storage = carbon stock at a given time. Sequestration = net annual increase.
  - Storage (stock): Total carbon currently held in the soil.
  - Sequestration (rate): Net annual increase in that stock (measured as CO_2e/ha/yr).
  - Compost additions may increase stock temporarily, but true sequestration requires long-term gains beyond the baseline.
- **Carbon Inputs:** Roots, residues, compost, manure**.**
- **Carbon Outputs:** Microbial respiration, erosion, tillage losses.
  - Inputs (Build): Roots, residues, compost, manure, cover crops.
  - Outputs (Consume): Microbial respiration, erosion, tillage, harvest removal.
  - Maintain: Practices like reduced tillage and mulching that protect soil aggregates and slow carbon loss.
- **Build–Maintain–Consume Triad:** Practices fall into categories that either build, protect, or consume carbon**.**
- **Scaling Up:** Even a 0.1% annual increase in soil organic carbon across large farmland areas = gigatons of CO_2 equivalent.
- **Why It Matters**
  - Soils = the largest land-based carbon pool (more than vegetation + atmosphere combined).
  - Even a 0.1% increase in SOM across cropland could sequester gigatons of CO_2.
  - Carbon practices also co-benefit water infiltration, nutrient cycling, and resilience.

Carbon Detective Lab Extension (Classroom Exercise)

Introduction:

- Students receive mini-datasets (respiration rate, SOM %, infiltration rates).

- In groups, they:
    - Identify which soils are gaining vs. losing carbon.
    - Propose a 2-practice bundle (Build + Maintain).
    - Estimate the likely indicator shift (e.g., infiltration ↑, respiration ↓).
    - Map their practices to relevant SDGs (2, 6, 12, 13, 15).
- Groups present findings in a short “carbon action plan” memo.

Real-World Applications

- Carbon Markets: Farmers can sell carbon credits for sequestering CO_2.
- Case Study: Australia’s “Carbon Farming Initiative” – producers earn credits for building soil carbon.
- Trade-Offs: Compost addition may relocate carbon, while cover crops + reduced tillage generate net new sequestration.

NGSS Integration

Relevant NGSS Science Topics:

- **HS-LS2-4: Cycles of matter in ecosystems (focus on carbon).**
- **HS-LS2-5: Evaluate ecosystem carrying capacity in relation to carbon stocks.**
- **ESS3.C: Human impacts on global systems.**
- **ETS1.B: Designing solutions with trade-offs (carbon practices).**

Ask Students:

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

<u>Option 2: Technical Lecture on Root Microbiome Engineering via Metabolic Modeling</u>

Introduction

This lecture invites students to dig deeper into soil carbon dynamics by comparing carbon storage (stock) and carbon sequestration (rate of increase). Students analyze datasets (respiration, SOM %, infiltration) and use the Build–Maintain–Consume framework to classify practices and design strategies.

System Inputs and Outputs

Component	Input	Output
Soil Carbon System	**Plant biomass, compost, cover crop residues**	**Soil organic matter, microbial respiration (CO_2), erosion losses**
Managed Practices	**Cover crops, no-till, biochar**	**Increased SOM, reduced disturbance losses, stabilized aggregates**

Modeling Interactions

- Positive feedback: Repeated tillage accelerates decomposition, which lowers SOM, further degrading structure and increasing losses.
- Negative feedback: Cover crops add biomass, build structure, and slow decomposition, stabilizing carbon stocks.
- Energy & Matter Flow Mapping: Photosynthesis captures CO_2 → stored in roots/exudates → microbes transform into SOM or respire back as CO_2.
- Material Cycling: Practices can shift the balance toward long-term SOM storage versus short-term release.

Carbon Accounting Metrics

- Carbon Stock (Storage): Measured in t C/ha; represents current soil organic carbon.
- Sequestration Rate: Annual change in stock (Δ t C/ha/yr).
- Emission Factors: Use respiration data or lab CO_2 fizz tests as proxies for microbial release.

Data-Driven Decision-Making

- Mini-dataset example:
    - SOM % = 1.8% (low)
    - Respiration = high
    - Infiltration = moderate
    - → Likely outcome: Net carbon loss without management changes.
- Decision: Introduce cover crops (Build) + no-till (Maintain) → predict increase in SOM, decreased respiration rate, improved infiltration.

Benefits of Technical Modeling

- Clarifies which practices actually build net new carbon rather than simply relocate existing carbon.
- Supports climate policy and carbon credit programs (verification requires accurate accounting).
- Links soil health directly to SDG 13: Climate Action and co-benefits like water quality (SDG 6) and food security (SDG 2).

Ask Students:

- Given a dataset (SOM, respiration, infiltration), can you classify whether this soil is building or losing carbon?
- Which practice bundle would you choose to shift the trend, and how would you justify it to a farmer?
- If you were designing a carbon market, how would you verify sequestration versus short-term storage?

NGSS Integration and Student Reflection

Relevant NGSS Science Topics:

- **HS-LS2-4: Use a model to illustrate the cycling of matter in ecosystems (carbon cycle).**
- **HS-LS2-5: Evaluate ecosystem carrying capacity in relation to carbon storage.**
- **ESS3.C: Human impacts on Earth systems — soil carbon as a climate tools.**
- **ETS1.B: Designing solutions considering trade-offs — carbon practices.**
- **Crosscutting Concept: Cause and effect — small soil changes scale up to global climate outcomes.**