Soil Health & Regenerative Agriculture

FOR THE HIGH SCHOOL CLASSROOM

American Farmland Trust
SAVING THE LAND THAT SUSTAINS US

USDA National Institute of Food and Agriculture
U.S. DEPARTMENT OF AGRICULTURE

FRONT COVER PHOTOS

Top left: Teachers completing a rainfall simulator activity in the classroom.

Third down on the left: Teachers observing cover crops and their root structure.

Right: Teachers exploring soil peds during a hands-on activity.

contents

Curriculum writer Candy Thomas explaining soil structure to a group of teachers.

Lesson Overview

Introduction to Soils

NATIONAL AGRISCIENCE STANDARDS

CS.04.01.01.b.	Analyze available practices to steward natural resources in AFNR systems
NRS.01.02.05.a.	Research and examine the characteristics used to identify non-living resources
ESS.05.02.02.b.	Assess different measurements of soil quality
NRS.01.05.04.a.	Compare and contrast techniques associated with soil management (e.g., soil survey and interpretation, erosion control, etc.).
NRS.01.05.04.b.	Analyze a plot of land in order to determine which soil management techniques would be most applicable.
NRS.01.02.	Classify different types of natural resources in order to enable protection, conservation, enhancement, and management in a particular geographical region.

NEXGEN SCIENCE STANDARDS

HS-ESS3-1.	Construct an explanation based on evidence for how the availability of natural resources, the occurrence of natural hazards, and changes in climate have influenced human activity.
HS-ESS3-3.	Create a computational simulation to illustrate the relationships among the management of natural resources, the sustainability of human populations, and biodiversity.
HS-ESS3-6.	Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.

Key Concepts

1. How is soil formed?
2. What makes up soil?
3. Why is it important to build soil?

Vocabulary

- Soil components
- Sand
- Silt
- Clay
- Loam
- Texture
- Soil Horizons
- Organic Matter
- Soil pH
- Porosity
- Permeability
- Aggregate
- Soil Formation Factors (parent material, climate, biological factors, topography, and time)
- Soil Structure

Prior to the start of the lesson, give a pre-test if applicable. Teachers are also encouraged to think of soil samples for future use and plant a cover crop, such as rye, in an aluminum pan if they have no cover available for future use.

Day One

Materials: soil texture triangle (or Soil Texture Calculator | Natural Resources Conservation Service (usda.gov)), sand, silt, clay samples, PowerPoint

Interest Approach (10 minutes): Ask students to create their own KWL board by writing down things they KNOW about soil, WANT to know, and have LEARNED. Once students have created their lists, compile a list of these items, by category, to reference in the future.

Content (35 minutes including use of the triangle): (show PowerPoint presentation)

After completing the KWL with students, discuss the Key Concepts and Vocabulary. Encourage students to take notes throughout this section or print the notes for the students to follow along.

To start our lesson on regenerative agriculture, we must start at the basis of all life: soil. Soil is composed of both living and nonliving materials. Today, we are going to discuss the non-living particles that comprise **soil texture**. Soil texture refers to the proportion of sand, silt, and clay-sized particles in the soil.

Sand is the largest particle in soil. Some soils are composed mostly of sand - think of sandy beaches. Sand ranges in size from 2.0 to 0.05mm in diameter. It is often the easiest particle to feel in soil. *Pass sample of sand around classroom. Ask students to describe the feel of sand; for larger classrooms or to save time; ask one student to feel and describe to the class.*

Silt is the next-sized particle in soil. It ranges in size from 0.05 to 0.002mm. Some soils are also composed almost entirely of silt. *Pass sample of silt around classroom. Ask students to describe the feel of silt; for larger classrooms or to save time; ask one student to feel and describe to the class.*

Clay is the smallest particle in soil. Clay has a diameter of less than 0.002mm, making it the smallest. It is also the particle that is the easiest to compact. Clay has often been used throughout history to make pots and other ornamental pieces. When you think of compaction, clay can be smooshed together due to its small size to make clay pots, which allows very little air to exist between the particles. If you compare that to sand, a lot of air can exist around the particle, making it difficult to smoosh together. *Pass sample of clay around classroom. Ask students to describe the feel of clay; for larger classrooms or to save time; ask one student to feel and describe to the class. Students can also wet the clay with a small amount of water to feel the differences.*

Porosity and **Permeability**. Porosity is the number of pores, or open spaces between soil particles. Fine-textured soil has more pore space than coarse-textured soil because more particles can be included in a unit volume as compared to larger ones. Soils with a high degree of porosity mean that water is more readily absorbed. Permeability is the amount of connectivity between soil pores. Soils with a high degree of permeability mean that water runs through quite easily. Can you guess which of these three samples has a high degree of porosity? (*Clay)* How about permeability? *(Sand)* We will continue to visit this topic as we move throughout this unit.

Now, you have seen three soil particles, but do these samples look like soil you see in a field, yard, or even around our community? No, because these particles rarely exist as the sole component in soil. Most of the time, they are combined as percentages of relative amounts that give soil its texture. Here is the soil texture triangle. *Pass around soil texture triangle provided. You can also use the link provided by NRCS if you prefer to have a digital version. Ask students what they notice about the triangle.*

The soil texture triangle has three sides, representing percentages of the three soil particles we have discussed. It also has types of texture by percentage within the triangle. For example, if we have soil that is 65% sand, 30% clay, and 5% silt, we have sandy clay loam. *Provide students with several more examples to practice using the soil texture triangle.*

Homework: Ask students to bring in different types of soil from their home, school, or community. *Teachers are advised to keep multiple soil samples in their classroom for tomorrow's activity. You may also provide soil samples and skip homework for students.*

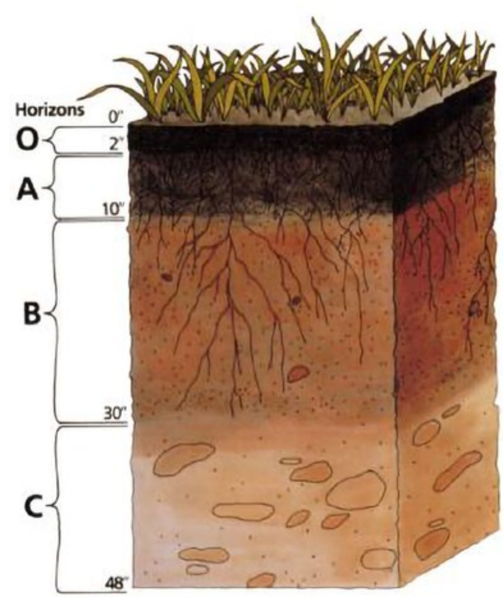
Day Two

Materials: Paper plates, soil samples, Ziploc bags, PowerPoint

Interest Approach (10-15 minutes): Lay out different soils from different locations for students to "guess" what the soil is made of and hypothesize how the soil was formed. *Use the "guide to texture by feel" document and slides to walk through the scientific way to determine what the sample is made of.* Include student samples from homework assignment if applicable. Put the soil samples to the side for later use.

Content (30-40 minutes): Yesterday, we learned that soil is made up of clay, silt, and sand by observing those components and by using the soil texture triangle. But we also learned that soil doesn't usually look like any of those components. Why do you think that soil, as we saw in our activity this morning, looks different than the samples we saw yesterday? *(Anticipate answers like "it is black/brown, there are other things like roots in it, etc.)* To answer that question, we must look at several factors that influence what soil looks like.

Today, we will discuss soil horizons and formation factors.



Soil Horizons are soil layers that differ in many properties, including color, texture, structure, thickness, and chemical/mineral content. Soil scientists use the letters O, A, E, B, C, and R to identify the horizons. However, not all soils have each horizon, and the thickness of each horizon can vary greatly from the picture seen here. The "O" horizon stands for organic and includes organic materials from leaves in forests and dead plant material in prairies. Where might we see soil that does not have an "O" layer? (*Anticipate answers such as top of a mountain or in areas where plants may not grow.)* The A horizon or topsoil is mostly minerals from the parent material and organic matter added. It's a good place for plants, soil organisms, and roots to grow. E is the eluviated horizon; it is leached of clay, minerals, and organic matter, and is sandier and lighter in color than the A horizon. You may not find it in every soil type. The B or subsoil horizon is rich in minerals that moved down from the A and E horizons, also not present in all soils. C is the parent material from which all soil is developed. It contains soil and rock from the lower layer of bedrock. R or bedrock is a rock mass that forms the parent material for some soils if close enough to the surface to weather or contact with lichens or moss. These horizons represent the physical, biological, and chemical processes that soils go through during development.

> **Teacher bonus activities***: There are several ways to visually create soil horizons for students. You might consider adding a bonus activity of creating "soil pudding" using cookies and different layers of pudding to represent soil horizons. NRCS has an activity to create Soil Profile Cards found here:* A Soil Profile | Natural Resources Conservation Service (usda.gov)*. Another activity would be visiting a soil pit. Contact your local NRCS or SWCD to help dig a pit or view one already dug in your area.*

Soil formation factors are parent material, climate, topography, time, and biological activity.

Parent material is the type of rock or mineral in which the soil was formed. The material could have been bedrock that weathered in place. These "residual" soils have the same general chemistry as original rocks. More commonly, soils form from materials that have moved from elsewhere. Wind, ice, or water can all move soils, and frequently do. Windblown "loess" is common in the Midwest, which buries glacial till in many areas. Glacial till is a material ground up and moved by a glacier. Alluvium is sediment along the rivers that has different textures depending on the speed of the river.

Climate is the weather conditions prevailing in an area, in general or over a long period (Oxford Dictionary). Temperature and moisture influence the speed of chemical reactions, which help control how fast rocks weather and dead organisms decompose. Soils develop faster in warm, moist climates and slowest in cold arid ones.

Topography is the arrangement of the natural and artificial physical features of an area (Oxford dictionary). The shape of the land and the direction it faces make a difference in how much sunlight the soil gets and how much water it keeps. Deeper soils form at the bottom of a hill than at the top because gravity and water move particles down the slope.

Time also affects the soil. Over time, soils exhibit features that reflect the other forming factors. Soil formation processes are continuous. Soil is nearly always changing due to other formation factors. Older soils differ from younger soils because they have had longer to develop.

However, we haven't discussed the last soil formation factor. This factor is one that we will spend the most time on in this unit, as it involves our management actions as it relates to soil. The last soil formation factor is **biological factors**.

Plants, animals, micro-organisms, and humans affect soil formation. Let's brainstorm ways that humans, animals, plants, and microorganisms affect soil.

Create 4 columns on the board. Label each column "humans," "animals," "plants," and "micro-organisms." Facilitate discussion with the class and add ways that biological factors affect soil. Below is a sample graph, but it is not all-inclusive. Encourage thoughts about ways these biological factors interact to form soils.

PLANTS	ANIMALS	HUMANS	MICRO-ORGANISMS
Leaves from plants fall to the surface and decompose on the soil.	Animals (such as moles) live in the soil and dig complex systems underground.	Farmers and ranchers are caretakers of soil. (Management practices such as tilling)	Organisms decompose leaves and mix them in the upper part of the soil.
Fibrous roots fill soil space.	Animals die and decompose into the soil.	Build buildings, homes, parking lots, etc on top of soil.	Chemical exchanges between roots and soil
Tree and shrub roots often dig deep into the soil and break apart rocks at deeper layers.	Adding fertilizer to the soil.	Mow and maintain lawns and gardens.	
	Earthworms create channels underground.		

Sources: Soil Facts | Natural Resources Conservation Service (usda.gov)

Day Three

Materials: 1 computer per student, table from day 2, Web Soil Survey Scavenger Hunt Worksheet

Interest Approach (5 minutes): Consider the table we created yesterday. Create a table of your own and add two additional ways that plants, animals, humans, and microorganisms might affect the soil. *(Give approximately 1 minute to do this.)* Now, let's share your ideas with the person sitting next to you. (*Teachers may assign partners as needed instead. Give approximately 1 minute here.)* Now, would anyone like to share their partner's ideas with the class? (*Write ideas on the graph from yesterday.)*

Content: For today's lesson, we are going to complete a scavenger hunt using the USDA's Web Soil Survey. There are a lot of uses for this database, but today we are going to explore soil types around our school, home, and national interests. *Pass out the scavenger hunt worksheet.*

Tour of the Website (10 minutes): *Teachers should familiarize themselves with the functions of the website prior to teaching the lesson.*

Students should complete the worksheet/scavenger hunt. ~30 minutes. (Time may vary by student/ability level. An idea to expand this activity is to allow additional time to explore the website, or students can present their findings to a group or the class.)

Day Four

Interest Approach (3 minutes): Think of building a house. To build a house, what things would you need? What kind of structural components would a person need to build a strong house? Write for 2 minutes about how you would build a structurally strong house.

Content (20 minutes): Soil has structure; it is made up of components that, when they work together, provide different materials, like when you build a house. The soil particles, which are like bricks when they all come together, build a structure like a home. The glue and nails that hold all the soils together are aggregation and come from soil biology or microbial glues, roots, and fungal hyphae that stabilize the soil structure and create a series of rooms, windows, and doorways. The arrangement of the different components creates windows, doors, and rooms. The cover on the surface acts as a roof. To protect the structure. Soil structure is the spatial arrangement of soil particles into small clumps, called peds or aggregates. Soil particles (sand, silt, clay, and even organic matter and biology) bind together to form these peds or aggregates. Peds or aggregates have various shapes depending on their texture and on the conditions in which they formed: getting wet and drying out, freezing and thawing, plant roots, and from the interference of people. They can resemble balls, blocks, columns, and plates. In between the peds are spaces or pores where water, air, and soil animals move and live.

Some soil structures are considered structureless, for example, single-grained, where there is no aggregation or ped formation. Consider your sandy beach or a crop field that is blowing in the wind as single-grained. Some that are composed mostly of clay can compact together to form a massive structure; there is no pore space.

The four principal soil ped shapes are spheroidal, platy, prism-like, and block-like. The spheroidal can be granular or crumbly, depending on poor space, and are found predominantly in the A horizon. They range from less than 1 mm to 10 mm in diameter.

A natural platelike structure, relatively thin horizontal sheet-like peds, will be found in the E horizon. You can also find it at the surface in the A horizon when compaction occurs due to man's interference. Platy structure is often created by man from tillage during wet periods or overgrazing and is a product of time and space, or too many animals in too long a period. It ranges in thickness from 1mm to 10mm. Block-like structure is mostly common in the B horizon, but can also be seen in the A horizon when someone stops tilling and starts adding cover crops, or eliminates pesticides and uses green manure as a resource that is disked in.

Blocky peds are irregular, rough, and shaped like a die. They can be described as angular when the edges of the peds are sharp, and the faces of the peds are distinct, or they can be subangular. Subangular peds have some rounding of the edges, as if they have been shaved off. They can range in size from 5 to 50mm across.

A prism-like structure is either termed columnar or prismatic. They are characterized by vertically oriented prisms or pillar-like peds that vary in size among different soils. They can be around 10 to 500 mm in diameter. Columnar, which is a pillar-like ped with the tops of the pillar being rounded off. These can be indicative of saline soils. When the top of the pillar is flat, that is termed prismatic. It is often associated with swelling-type clay. It is indicative of soils in semi-arid or arid environments in the B horizon. These types of structures allow deep percolation of water into the ground, and plant roots can then find the edges of these prisms and follow them down to find nutrients. In humid regions, prismatic structure sometimes occurs in poorly drained soils.

When describing these types of structures, a soil scientist will describe the type as above and from Very fine, fine, medium coarse to very coarse, and the degree of the development or how prevalent they appear as structureless, strong, moderate, or weak. It's best to observe this when the soil is dry. When they are wet, the peds will swell, and the distinction will disappear or be less defined.

References

Brady, N. and R. Weil. 2017. The nature and properties of soil, 15th ed. Library of Congress pub. ISBN: 9780133254488

Schoeneberger, P.J., D.A. Wysocki, E.C. Benham, and Soil Survey Staff. 2012. Field book for describing and sampling soils, Version 3.0. Natural Resources Conservation Service, National Soil Survey Center, Lincoln, NE.

Lesson Overview

Minimizing Disturbance

NATIONAL AGRISCIENCE STANDARDS

ESS.03.04.02.c.	Develop strategies for negating air pollutants based on soil microbial populations (e.g., carbon sequestration and rates of decomposition).
ESS.03.02.	Apply soil science and hydrology principles to environmental service systems.

NEXGEN SCIENCE STANDARDS

HS-ESS2-2.	Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems
HS-ESS3-2.	Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.*
HS-ESS3-4.	Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

Key Concepts

- What is an aggregate.
- Types of disturbances and impacts.
- What is water infiltration.

Vocabulary

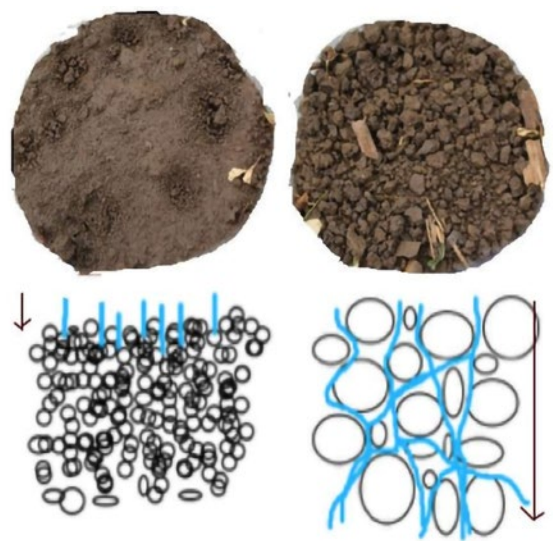
- Aggregates
- Tillage
- Soil Movement
- Compaction
- Chemical disturbance
- Biological disturbance
- Food webs
- Water holding capacity
- Infiltration
- Aggregate Stability

Day Five

Materials: Link to PowerPoint, link to water infiltration video: https://www.youtube.com/watch?v=pSRBb9YNs0E, Aggregate stability test supplies

Interest Approach (10 minutes): Complete an infiltration test outside with students by breaking them into groups. You can also demonstrate the test for students to observe. OR if outside space is not available- watch the above video. Ask students to write down what they have learned about soil so far. What types of material make up soil? How do those materials interact with each other? How could this contribute to the differences in infiltration that they observed (in person or via the video)?

Content (10 minutes): Aggregates are clumps or units of soil made of sand, silt, and clay. Soil structure is specific to the size, shape, and arrangement of the soil aggregates and the pore spaces between them. These aggregates are arranged in layers within the soil. Well-aggregated soils will have the ability to drain better, as they have larger spaces between them.



Unstable aggregates lead to reduced infiltration and surface sealing (left). Stable aggregates permit better infiltration (right).

Aggregate stability is important because stable particles are less inclined to collapse into smaller pieces. This decreases erosion and the power of erosion. These well-structured soils have a higher water holding capacity, are less prone to collapse, and **compaction**. Soils with poor structure will likely cause more problems. Problems such as compaction, erosion, crusting, runoff, and poor root development. When aggregates collapse, they fill the pore spaces, restricting permeability as they become sealed off. This also limits a plant's roots from developing deep into the soil.

There are many properties that affect aggregate stability. Soil texture, climate, organic matter, and availability of soil organisms. Silt and clay bind particles together better than sand. (opportunity to reference previous lessons on soil intros). Plants, animals, and soil microbes provide the glue (glomalin coats and protects, and poly saccharides, bubblegum-like, root exudates, which are sticky) that holds soil together. Diverse and active organisms work together to improve aggregate stability through secreting compounds. These aggregates are very delicate and can turn over within 27 days if not protected.(Six et al. 2004).

Frequency and intensity of rainfall also impact aggregate stability. Aggregates can be broken down by intense rainfall events. Warmer weather also impacts the rate of decomposition in the soil. Faster decomposition can lead to a loss of aggregate stability through the loss of soil organic matter.

Activity (20 minutes): Review Aggregate Stability Test instructions with the class. It is suggested to either do this activity outside or cover the tables first. Break students into groups with their supplies and worksheet.

Example with pictures for teacher use: Wet aggregate stability/soil structure retention demonstration

Start with two similar soils that have different long-term management. In this example, we used an Askarben Silty Clay Loam soil with two different management systems that are side by side on the University of Nebraska Rogers Memorial farm near Lincoln. One was managed under continuous no-till since 1981, along with cover crops for the past 10 years with a corn-soybean rotation, and the other has the same rotation except it has been managed under a conventional tillage system and no cover crops since 1981.

Step 1. Place an even amount of surface soil from each management system in sink strainers.

Step 2. Immerse strainer in custard or similar bowl.

Step 3. Leave strainer of soil in bowl of water until each one is fully saturated. If necessary add extra water from the top to ensure both are fully saturated.

Step 4. Turn the strainers upside down on the cutting board. The long term no-till retains its structure because of superior aggregate stability (brownie) vs. the conventional tillage soil loses its structure because it has poor aggregate stability (pudding) after being saturated. Turn the board sideways and you can see how the soil/water move and allow students to touch each one to feel differences. Major discussion points include improved soil structure, aggregate stability, improved air exchange, improved nutrient cycling, avoiding anaeobic conditions, dentrification, runoff/erosion benefits, crusting, etc.

Sources

http://nmsp.cals.cornell.edu/publications/factsheets/factsheet95.pdf

Six. J, H.Bossuyt, S.Degryze, K.Denef. 2004. A history of research on the link between microaggregates, soil biota, and soil organic matter dynamics. Soil and tillage research, 79:7–31.

http://nmsp.cals.cornell.edu/publications/factsheets/factsheet95.pdf

Day Six

Materials: Link to PowerPoint

Interest Approach (10 minutes): Students should journal for 2 minutes, answering these three questions: From what we know about soil, what does it mean to disturb soil? What is a non-agricultural disturbance? What is an agricultural disturbance? Once students have finished, discuss as a class what disturbance means in relation to soil and answer the above questions as a class.

Content (20 minutes): Farmers must work to minimize disturbance to keep the soil healthy. Soil disturbance can occur in three different forms: biological, chemical, and physical. **Biological disturbance** impacts the biological communities utilizing the soil. Whether that is the plant currently growing or the microbes that live in the soil. **Chemical disturbance** is the overapplication of nutrients or pesticides. This disrupts the soil food web and its functions. **Physical disturbance** can occur in tillage and other physical disturbances of the soil layers.

Biological disturbances in agriculture can occur via overgrazing. Outside of agriculture, this can look like over-mowing a lawn. The loss of green tissue limits the plant's ability to photosynthesize. This overall reduces the productivity of that plant in the soil and the interactions between that plant's roots and the soil microbiome. One more way soil can be biologically disturbed is by adding biologicals that are sold in a jug. They have different species composition and can be consumed rapidly by the current soil biology or take over and eliminate native soil biology. Soil biology suffers from increased erosion exposure, increased soil temperature, and decreased root growth and exudates.

Chemical disturbance is the overapplication of inputs. Those chemical inputs can be fertilizers or pesticides. The overapplication of fertilizers can disrupt the natural soil food web through unequal distribution of chemicals. Overapplication of pesticides like fungicides, some herbicides, and insecticides can wipe out the soil microbiome completely. However, it may be necessary to control pests that would wipe out a farmer's crop or cause a disease if it is a particularly bad year for it.

Physical disturbance occurs naturally in nature. Earthquakes, erosion, and the movement of glaciers across the landscape. Fire is a biological and physical disturbance, as well as extreme weather conditions, such as drought, floods, and tornadoes. In an agricultural setting, physical disturbance is tillage. Strip, reduced, and conventional tillage disrupt the soil. Tillage physically breaks down the soil aggregates and destroys root and earthworm channels as well as the pore spaces between the soil aggregates. The soil mixing with oxygen releases excess carbon dioxide into the atmosphere. This also reduces overall soil organic matter and quickly mineralizes nutrients in a short burst rather than allowed to mineralize slowly over a season and feed the crop. It is important to note that growing food, fiber and fuel will require the soil to be disturbed, but working to minimize the disturbance is the goal.

Let's use a real-life example of a farmer working to minimize disturbance on a field. A corn farmer goes to check his field before planting his corn. He already purchased the seed for $300 a bag. A weed is growing in the field at a fast rate. The farmer is afraid that if the weed is left unchecked, it will completely shade out his young corn plants, killing them and costing him thousands of dollars (remember- he already paid for the corn seed!). Which should he do- nothing, spray the field with a herbicide, or till the soil? *Draw a table like the one below on the board and discuss, as a class, the pros and cons, and ultimately what the farmer should do. Examples are listed for guidance. Consider economic variables. In reality, the goal of the activity is NOT to decide which one the farmer should do, but to understand the number of variables farmers may be working with to make these decisions.*

WHAT SHOULD THE FARMER DO?	PROS	CONS
Option 1: **Farmer does nothing**	Soil remains undisturbed	Weeds "shadow" out his corn crop
Option 2: **Farmer sprays the weeds with a herbicide**	Weeds are killed Soil is not compacted as much as tilling	Chemical can be expensive
Option 3: **Farmer tills his field**	Weeds are killed Likely an immediate fix	Fuel is expensive to pull tillage equipment Compaction from equipment

Extension activities: Play the fishing game: https://cloudinstitute.org/fish-game, and discuss as a class how disturbances are shown in the game and the role of people in this.

Day Seven

Materials: Variable speed blow dryer with a flat sheet pan no more than 4 inch high in height, soil with good aggregation vs poor aggregation from a regularly tilled field, white paper with cooking spray, wind barriers (you can cut very small branches no more than 2–4 inches in height to poke in the soil.

Interest approach (10 minutes): Watch the video about the Dust Bowl: History Brief: the Dust Bowl—YouTube. Once finished, have students answer this question by journaling: Could the Dust Bowl happen again? Why or Why Not? Discuss opinions. Remind students how management decisions led to the Dust Bowl.

Content (12–15 minutes): Erosion is the process by which earth materials are worn away and transported over time by natural forces (water and wind). Erosion is the opposite of deposition. The top layer of soil, known as topsoil, is the fertile, life-giving layer. When the topsoil is exposed to strong winds, hard rains, and flowing water, erosion occurs. Overgrazing of animals can also lead to large areas of soil being uncovered and susceptible. About 60% of the soil that is washed away ends up in streams, lakes, and rivers, as well as whatever has been applied to the soil and is trapped within the sediment. These nutrients and agrochemicals can lead to harmful fish-kills and algal blooms. Highway construction and home construction can also lead to the loss of topsoil and massive erosion.

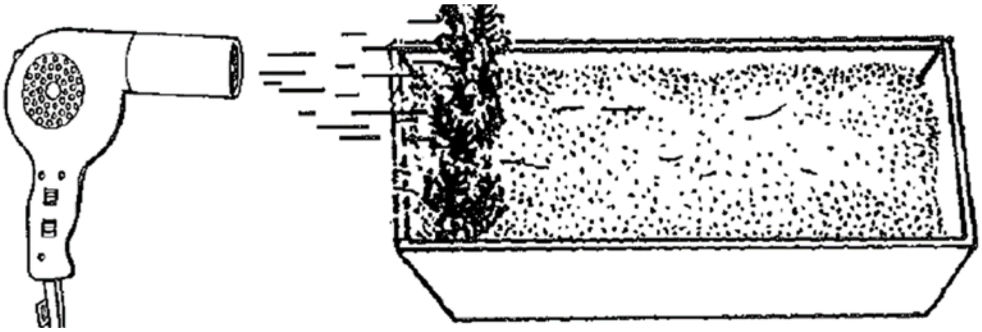
There are multiple forms of water erosion across landscapes. Sheet erosion, rill erosion, gully erosion, and bank erosion.

Soil types that are more likely to be loose, dry, and fine are more likely to be erodible. Vegetation makes soil far less susceptible to erosion. Like water erosion, wind erosion occurs when wind picks up the soil and deposits it elsewhere. Wind erosion also impacts overall air quality and visibility, which can lead to health risks.

Option to review this video instead of performing the experiment. Wind Simulator: https://www.youtube.com/watch?v=ETRK0tUKMjA
or https://www.youtube.com/watch?v=PQmon7Rj6ns

Content: Run the Wind Simulator

- Variable speed Blow dryer with a flat sheet pan no more than 4 inches high in height, soil with good aggregation vs poor aggregation from a regularly tilled field, white paper with cooking spray, wind barriers (you can cut very small branches no more than 2-4 inches in height to poke in the soil.
- Procedure: Set the panful of soil on a table, place a drop cloth on the floor or tarp if indoors to reduce mess. Place the paper down on the table, to the right of the pan, as shown below in the photo. Coat the surface of the paper with cooking spray.



- Turn on the hair dryer first at a very low speed and notice that there are no branches on it. Notice how the soil moves right at the end of the hair dryer. Focus on the three types of soil movement. Saltation is the bunch of soil particles across the surface of the soil in the pan. As the saltating particles leave the surface and hit the surface further down the pan, we have crept the particles. It bumps into and puts more particles in motion. Turn up the hair dryer. As more force across the surface is exerted, saltation can come into contact with surface roughening, and you get suspension or fine particles of clay disperse into the atmosphere, and will land on the paper at the end of the pan. Do the same above with the no-till pan and discuss the difference.
- Now place the vertical barriers or little branches as seen above and turn on the blow dryer first on low, then make it go higher and move closer to the pan. What impact does the barrier have on the soil? What will the barrier do besides slow down the wind? Discuss the principles of keeping the soil covered, how it keeps soil particles in place, and allows increased moisture, which is resistant to wind erosion.

Additional Activity Soil Water Lesson Plan: https://www.nrcs.usda.gov/sites/default/files/2022-10/soil_water_lesson_plan.pdf
To make this, you can use some aluminum bread pans full of soil from the field and put a cover on the good soil, as shown in the link for the Soil Water Lesson Plan. You can poke numerous holes in the bottom of them instead of making the metal cutters.

Extended Opportunity: Collaborate with Social Studies or History teachers to discuss content around the Dust Bowl. What caused it, and what is the historical significance of this event? Hugh Hammond Bennet (father of soil conservation) introduced new farming methods with the support of President Roosevelt. Establishment of the Civilian Conservation Corps.

https://www.aaas.org/dust-bowl-wake-call-environmental-practices#:~:text=Some%20of%20the%20new%20methods,of%20the%20new%20farming%20methods.

Sources

https://www.nrdc.org/stories/soil-erosion-101#water

https://extension.unr.edu/publication.aspx?PubID=4867

https://greencover.com/soil-disturbance/

Curriculum writer Candy Thomas showing the results of the Kansas Association of Conservation District's rainfall simulator on differently managed soils.

Lesson Overview

Living Roots

NATIONAL AGRISCIENCE STANDARDS

SS.03.04.	Apply microbiology principles to environmental service systems.
ESS.03.04.01.b.	Assess how the activities of microorganisms in soil affect environmental service systems and ecosystem biodiversity.

NEXGEN SCIENCE STANDARDS

HS-ESS3-1.	Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity
HS-ESS3-2.	Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.
HS-ESS3-4.	Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

Key Concepts

- What do roots do?
- Why are roots important?
- Identify different types of roots.
- What are cover crops?
- How do Carbon & Nitrogen interact in the soil?

Vocabulary

- Mycorrhizal fungi
- Symbiosis
- Nutrient efficiency
- Fibrous
- Taproot
- Cover crop

LESSON 3

Day Eight

Materials: Root photos from PowerPoint (printed with magnets if desired), PowerPoint, and different types of root examples if available. Optional: computer access for the Midwest Cover Crop Tool Selector

Interest Approach (5 minutes): Write the following names on the board (Sun hemp, hairy vetch, cowpea, alfalfa, yellow-blossom sweet clover) with space to attach (with magnets) pictures of roots with the corresponding name of a cover crop. Challenge students to work together to match the roots to the name of the cover crop. (*Alternate activity: show students the photos one at a time and have them guess by writing it down at their workstation)*

Content (30 minutes): First, review the root structure. A root is made up of many components, and these are vital to the root function for the plant. Zone of cell differentiation—where the plant cells acquire their fate features. Zone of cell elongation—cells increase their length, growing the root. Zone of cell division—actively dividing cells that are undifferentiated. Root Cap—tissue at the tip of the root. Xylem—vascular tissue responsible for water and mineral transport. Phloem—vascular tissue responsible for nutrient transport. Root Hair—sponge for nutrient and water absorption. Epidermis—the outermost layer of cells for the plant. Cortex—undifferentiated cell types in the plant root. Endodermis—innermost layer of the plant root. Pericycle—a layer of cells that surrounds the vascular tissue. The zone of elongation is important for the root to grow towards the water source.

The root hairs are important for nutrient and water absorption within the plant. Plants absorb water and nutrients from the soil through osmosis. This is the movement of water from areas of high concentration to low concentration. The ability of roots to grow towards wet or moist soil is called hydrotropism.

Roots will swell to store high-energy compounds like starch or sugar, think about a potato. Other roots will focus on proteins and nutrients, but typically they store high-energy carbohydrates.

Roots have a symbiotic relationship with **mycorrhizal fungi**. In a **symbiotic** relationship, both parties are actively participating, and the relationship is mutually beneficial. Mycorrhiza means fungus root. The natural infection of this fungus supplies the roots with sugars and carbon and receives water and nutrients in return. The excretions, exudates, from roots supply the plants with mineral nutrients that they can actively use. There are two types of Mycorrhizae, and they are classified based on their location, inside the root or outside the root.

Plants play an important role in building soil and improving soil quality, especially through their root systems. Scientists recognize that plants have various types, including fibrous and taproots. There are other types of roots, but for our lesson today, we will discuss these two types.

Fibrous roots are thin, branch-like roots that spread out in various directions from the plant's base. Many grasses, like wheat, rice, and corn, have a fibrous root system. Most cacti do as well. What might be the advantages of having a fibrous root system? *(Anticipate answers, such as can be broad reaching, lots of "branching," etc.)*

A taproot is a straight, tapering root growing vertically downward and forming the center from which subsidiary rootlets spring. Carrots, beets, and radishes all have a taproot system. What might be the advantages of having a taproot system? *(Anticipate answers, such as "ability to go straight down," a sturdy central root, etc.)*

Both types of roots provide anchorage, which we know is part of plant growth. However, plants also benefit the soil in multiple ways. First, the roots help anchor the soil down as well—a great deterrent for wind and water erosion. The roots hold the soil in place as wind or water passes. Additionally, roots absorb nutrients, such as nitrogen, from the soil. Absorption is important to farmers, particularly because nutrients help plants grow. If additional nutrients are not present in the soil or roots cannot absorb them, farmers must apply fertilizer to their crops. Fertilizers are an additional cost to the farmers.

Optional activity: If the season and time allow, have students examine the roots of various growing plants to observe differences in root structure. Ask posing questions, such as "Why do you think this plant's roots look the way they do?"

*This might be a good space for utilizing the Midwest cover crops tool or similar to explore different types of cover crops. Midwest Cover Crop Council—*Selector Tools – Midwest Cover Crops Council

Day Nine

Materials: USDA article, highlighters, ARS cover crop chart, PowerPoint

Interest Approach (10 minutes): Pass out USDA ERS—Cover Crops Can Influence Soil Health, Even Within the First Few Years After Adoption and highlighters to students. Ask students to read the passage and highlight information from the article that appears relevant to what they know about roots. Discuss the key takeaways from the article first with partners, then as a class. *(Although the article is short in length, it is highly technical reading—be prepared to assist students through some technical information as they read.)*

LESSON 3

As we read, **cover crops** can influence soil health. But what is a cover crop? A cover crop is any crop grown to cover the soil and may be incorporated into the soil later for enrichment. From what we learned yesterday about living roots, what might be some of the benefits of cover crops? Cover crops hold soil in place, often between cash crops. They help provide symbiotic relationships between the soil and microorganisms. They can also prevent nutrient loss, increase soil organic matter, suppress weeds, and disrupt pest cycles in plants. They provide secretions that help feed soil biology throughout the year. They provide carbohydrates, organic and amino acids, which are part of the diet of many lifeforms in the soil and above the soil. The exudates leaked out by roots help solubilize mineral nutrients for plants. Root hairs, the direct result of bacteria from inside the plant being expelled through the cortex, also help with the formation of aggregates by entangling and enmeshing soil.

Allow for a discussion point. Yesterday, we learned about living roots and how they serve plants and soil. What may be some benefits of a cover crop related to the soil and soil needs?

Let's explore a few different types of cover crops. Generally, they are broken down into—grasses, legumes, and broadleaves, which can be cool-season or warm-season. The seasonality of plants is the time of year when they grow the best. Cool-season plants germinate when soil temperature reaches 40 degrees, and many times require a cold period to germinate and flower. They can tolerate cold weather at or below freezing. Warm season plants require soil temperature to be above 50 degrees or more and are very susceptible to frost damage and will die if sustained cold temperatures below 32 degrees occur. They will only flower during the warm part of the year.

Grasses. Cover crops such as rye, winter wheat, barley, oats, annual ryegrass, and triticale are cool-season grasses. These cover crops are often the most common types of cover crops planted by farmers, as their growing seasons often fit between commodity crops, such as corn and soybeans. Grass cover crops help build soil health due to the root mass often accompanied by them. They can also help suppress weeds due to their dense growing population and help fight compaction. Weed suppression means preventing weeds from growing in an area, which can be helpful to farmers. Compaction can have a negative effect on a growing crop, as the soil is too hard for plants to grow, or the roots of a plant have to work hard to go around the compacted area.

Warm-season grasses that can be planted if your corn or soybean planting fails or after wheat are sorghum/sudan, teff, pearl millet, German millet, proso millet, and forage sorghum. These can also be used as a forage component following wheat or when a crop failure has occurred.

Legumes. Cover crops such as hairy vetch, crimson, red, white, blansa, berseem clover, and Sweetclover, alfalfa, fababeans, chickpeas, and lentils, and field peas are considered cool-season legumes. Warm-season legumes are cowpeas, mungbeans, forage soybeans, sunnhemp, partridge pea, lablab, and peanuts. Legumes can benefit soil by fixing atmospheric nitrogen (N) for subsequent crops. They can also attract beneficial insects, build soil matter, and prevent erosion.

Broadleaves. Cover crops can also include forbs, which are broadleaf plants that offer biodiversity. Examples of forbs include coneflowers, asters, and goldenrod in a perennial system. Cool-season forbs include mustards, turnips, radish, kale, flax, camelina, phacelia, and rapeseed. Many are day dependent on when they flower, so planting them in the late summer during August is a better option, so you don't get them going to seed. Warm-season plants that are grown after wheat or after a crop failure in a mix are buckwheat, chicory, safflower, and sunflowers.

How do farmers select which cover crops to use? There are many factors that farmers consider when thinking about cover crops. Farmers often look at the growing season of current crops. For example, in the Midwest, many farmers plant a corn-soybean rotation. Corn and soybeans typically grow from May to October in most parts of this area. A farmer might consider growing a crop that can be planted in the fall, overwinter, and be harvested or terminated in early spring. Some farmers may consider planting a cover crop alongside their crops to increase pollination or use the cover crop to feed livestock. Farmers also must consider what equipment they have for planting and harvesting cover crops. While some farmers may choose to grow cover crops alongside their other crops, many will need to factor in how to end the cover crop's growing season. Farmers may need to use chemicals or specialized equipment, such as a roller crimper or flail mower, to kill the cover crops. Some cover crops can also be winter killed by cold in some areas, these include the warm season grass, legumes, and broadleaf plants. Additional factors, such as the cost of the seed and available funding programs, may also play a role in cover crop decisions for farmers.

Let's look at the ARS Cover Crop Chart. The cover crop chart is separated into cool and warm-season crops. The grasses, legumes, and broadleaves that we discussed in this lesson are far more inclusive. We can also see their growth cycle: annual (meaning they complete their life cycle in one growing season and then die), perennial (plants that persist for multiple years and survive growing season to growing season), and biennial (live two years growing vegetation in the first and bloom in the second). Their architecture, how they grow either as an upright plant, they spread wide, or long prostrate close to the ground. Relative water use, low, medium to high. This tool is great for farmers to determine how a cover crop could work into their system and the needs of that system.

Day Ten

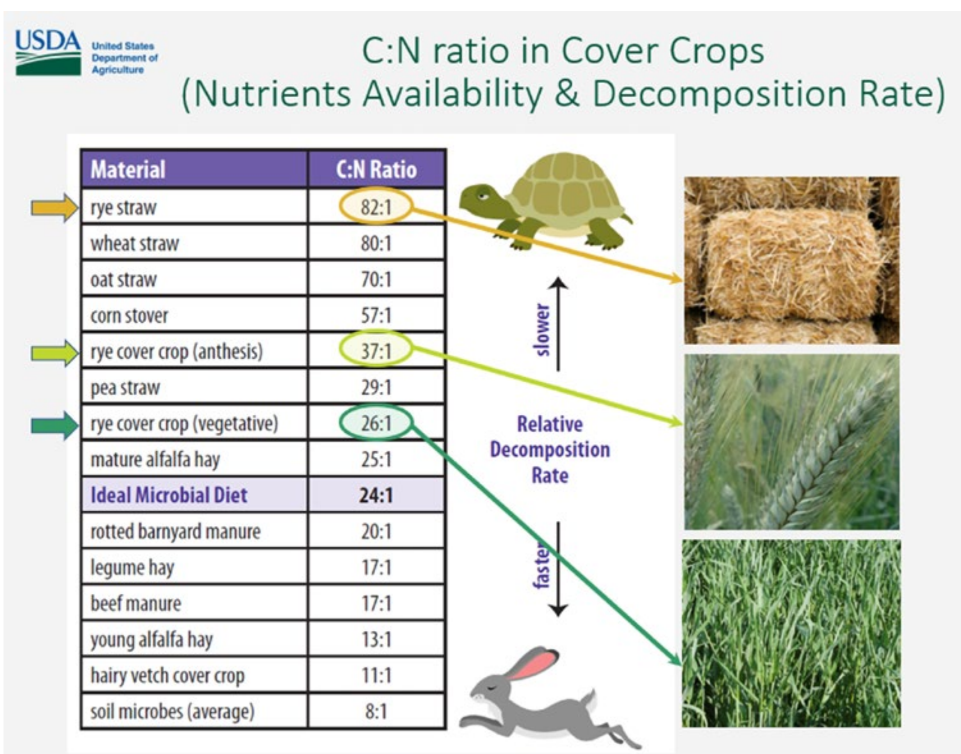
Materials: PowerPoint, NRCS Carbon to nitrogen ratio handout

Interest Approach (5 minutes): Chemistry Review Warm Up! Today, we are going to be using chemistry when discussing soil health. What does C (*draw on board)* stand for? N? *(Look for answers Carbon and Nitrogen.)* Ask students to do a 1-minute write about what they know about Carbon and Nitrogen. *It is important to understand that some students may not have taken a chemistry class yet—that is not needed, but this activity will help you be able to set them up for success and also gauge their chemistry knowledge.*

Content (30 minutes): When we consider adding more plants to a cropping system, either before or after a crop plant, we need to consider that we may have issues with nutrient tie-up. That can be a good thing if we overapply nutrients, as they can scavenge them, but it can also be detrimental to the following crop, depending on the growth stage of the cover crop that is to be terminated prior to planting. This growth stage is critical to nutrient availability or unavailability during cropping. All plants have a carbon-to-nitrogen ratio (*show example on cover crop chart from ARS).* The carbon-to-nitrogen ratio (C: N) is a ratio of the mass of carbon to the mass of nitrogen in a substance. For example, a C:N of 10:1 means there are ten units of carbon for each unit of nitrogen in the substance. Since the C:N ratio of everything in and on the soil can have a significant effect on crop residue decomposition, particularly residue cover on the soil and crop nutrient cycling (predominantly nitrogen), it is important to understand these ratios when planning crop rotations and the use of cover crops in agricultural systems.

Here is a typical scenario in cropping systems that contain corn or beans, and a cool-season cover crop is used.

Depending on whether you plant corn, you will need nitrogen to be available to that plant, and microbes are



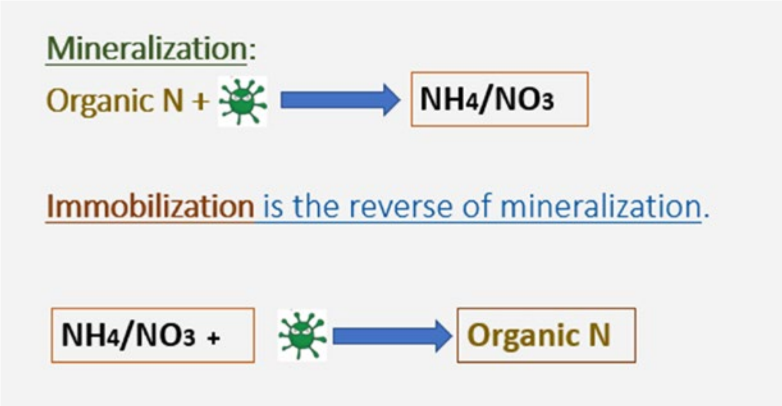
Material	C:N Ratio
rye straw	82:1
wheat straw	80:1
oat straw	70:1
corn stover	57:1
rye cover crop (anthesis)	37:1
pea straw	29:1
rye cover crop (vegetative)	26:1
mature alfalfa hay	25:1
Ideal Microbial Diet	**24:1**
rotted barnyard manure	20:1
legume hay	17:1
beef manure	17:1
young alfalfa hay	13:1
hairy vetch cover crop	11:1
soil microbes (average)	8:1

involved in breaking down all the plant biomass on the surface and the roots in the soil. To do that, they need a low carbon-to-nitrogen ratio of material or additional nitrogen to do so.

Soil microorganisms have a C: N ratio near 8:1. They must acquire enough carbon and nitrogen from the environment in which they live to maintain that ratio of carbon and nitrogen in their bodies. Because soil microorganisms burn carbon as a source of energy, not all of the carbon a soil microorganism eats remains in its body; a certain amount is lost as carbon dioxide during respiration. To acquire the carbon and nitrogen a soil microorganism needs to stay alive (body maintenance + energy) it needs a diet with a C:N ratio near 24:1, with 16 parts of carbon used for energy and eight parts for maintenance. It is this C:N ratio (24:1) that rules the soil!

If foodstuff such as mature alfalfa hay (C:N ratio of 25:1) is added to the soil (see Table 1), the soil microorganisms will consume it relatively quickly with essentially no excess carbon or nitrogen left over. The hay has an almost perfect balance of carbon to nitrogen that soil microorganisms (24:1) need. The process of eating these nutrients involves mineralization or immobilization.

Mineralization vs. Immobilization



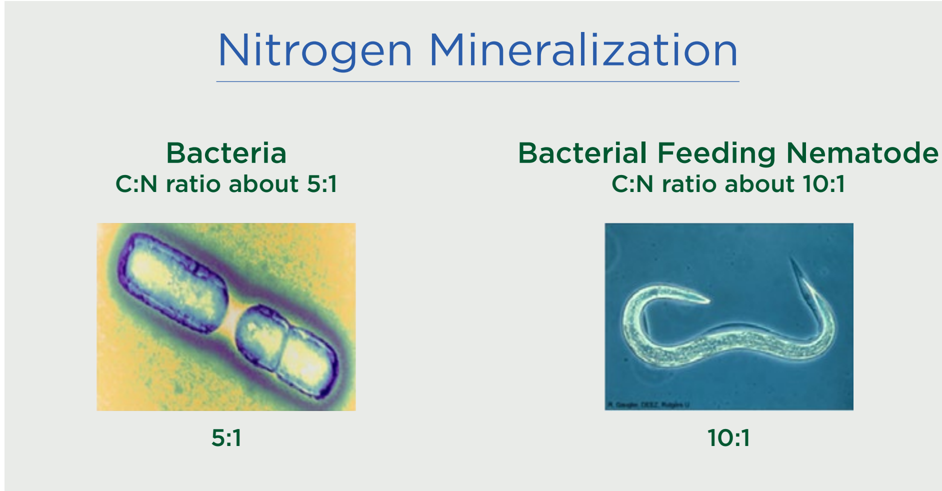
Mineralization is the process by which microbes decompose organic N from manure, organic matter, and crop residues to ammonium. Because it is a biological process, rates of mineralization vary with soil temperature, moisture, and the amount of oxygen in the soil (aeration).

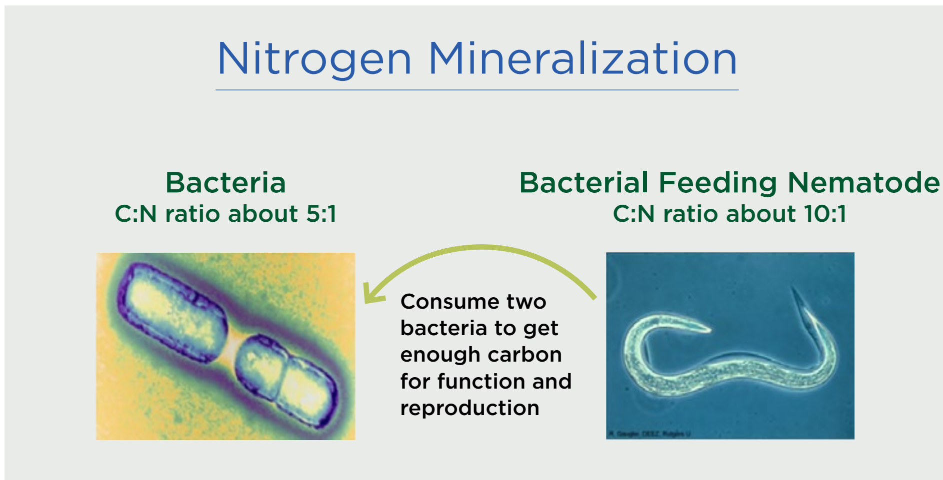
Immobilization is the reverse of mineralization. All living things require N; therefore, microorganisms in the soil compete with crops for N. Immobilization refers to the process by which nitrate and ammonium are taken up by soil organisms and, therefore, become unavailable to crops. This is only a small part of the process, but it gives a basic idea of how life, death, and mineralization work in that Rhizosphere.

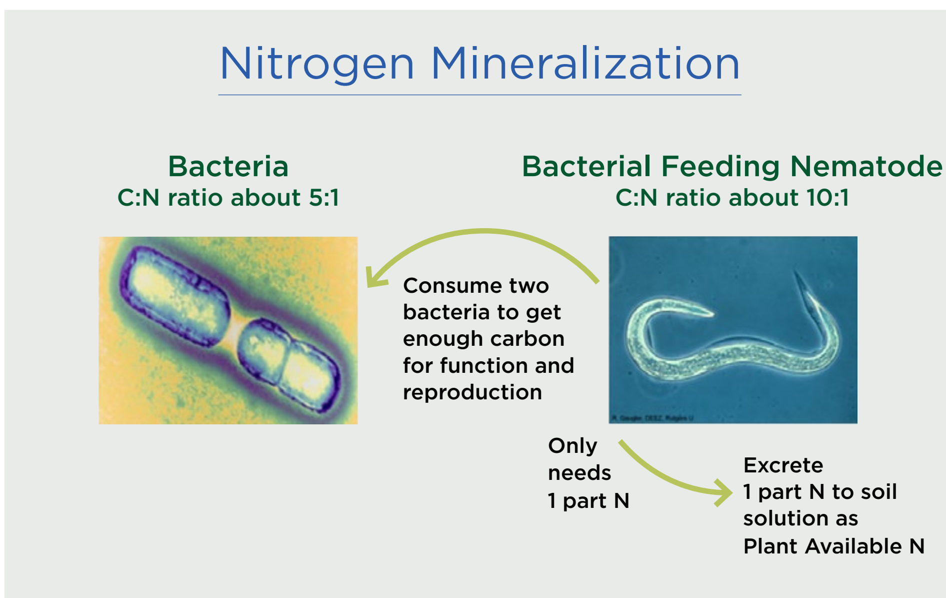
Everything is made up of differing amounts of carbon and nitrogen. C/N ratios vary between species but generally Bacteria have a lower C/N ratio than a Nematode.

Bacteria are around 5:1 and a Nematode, which eats the bacteria, is 10:1. A Nematode will need to eat two Bacteria to get 10 units of Carbon but it only needs one of the Nitrogen units.

So, he excretes the extra into the soil in a form that a plant can very readily take up. That is exactly what we want to happen if there is a plant there to take up that Nitrogen. This scenario works best after a low-carbon to nitrogen mix is planted before planting a high-







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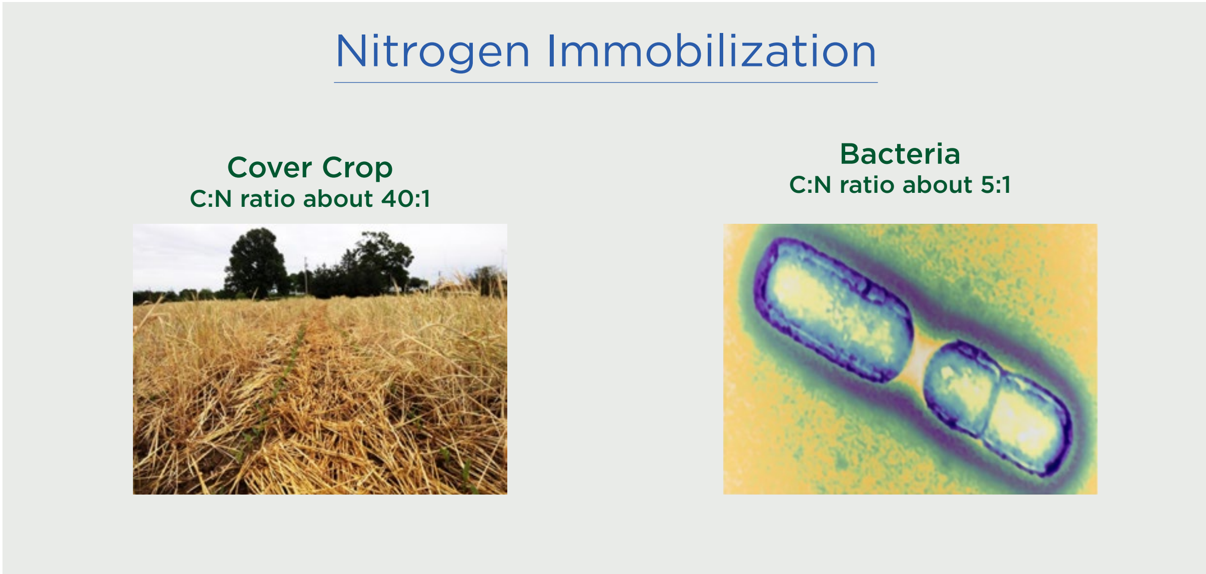
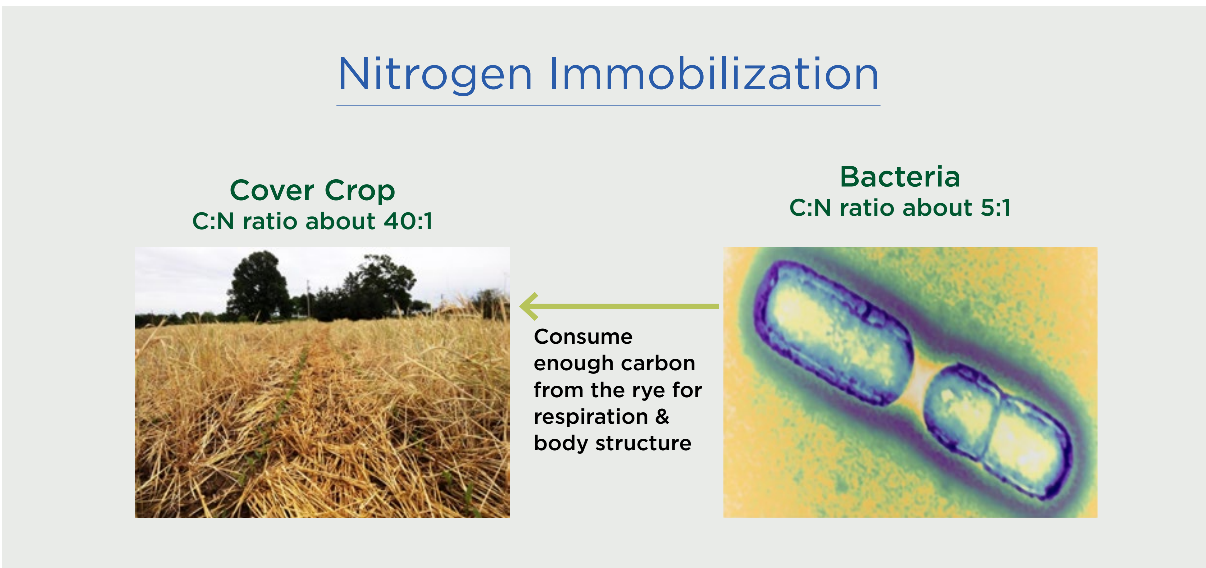
carbon to nitrogen plant like corn or wheat. This helps to reduce nitrogen losses after a crop is harvested.

You see the areas that are striped and look like there is more plant growth why is this? (Because the cereal rye is capturing the leftover nutrients in that row where the crop was previously planted.) Nitrate mineralized from crop residues and soil OM is highly soluble through the winter. Nitrogen leaching can be significant even without fall N applications.

If we were to plant corn into this high carbon-to-nitrogen ratio residue, the opposite would happen.

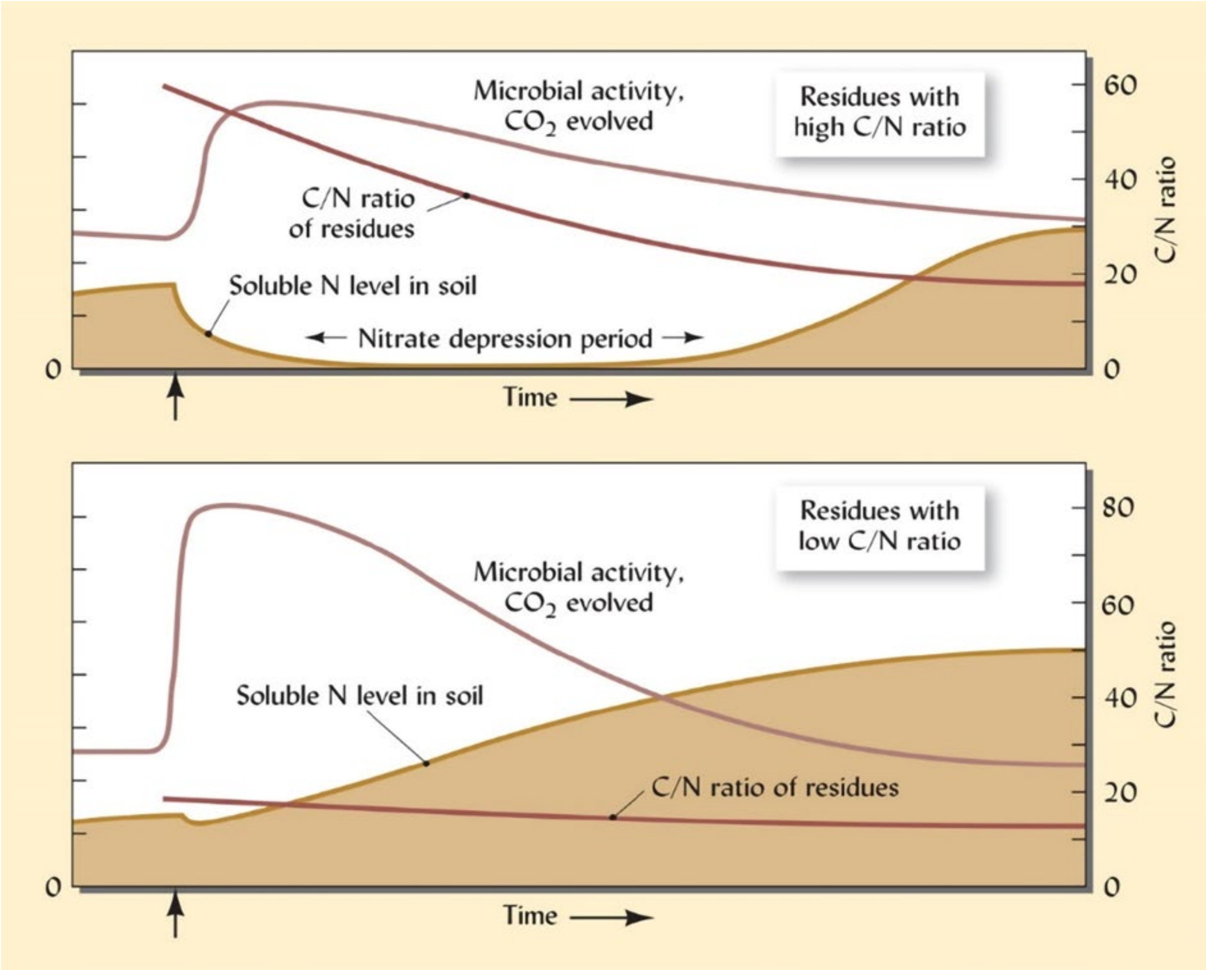
LESSON 3





In this scenario, the microbe takes its five carbons and one nitrogen, but there is a lot of carbon left over. So, if we exponentially multiply this out over billions of microbes, they will get their carbon, but the N is gone, so they start working on the Nitrogen in the soil, and your cereal rye that comes up in this residue will be starved for N. Therefore, you need to either feed additional N or you need to plant a lower C:N ratio cover, or a combination of the two. In the case of Organic, when you turn the green under, you have a quick food source available for microbes, and this process is sped up. You have excited the microbes by adding O_2 in the soil and gave them a food source so you need something that will feed that system N asap. I.e., composted manure, fish emulsion, etc.

Here is a good pictorial of the process from the Nature and Properties of Soil, of how the C:N is impacted by microorganisms.



Changes in microbial activity in soluble nitrogen level and residual c/n ratio following the addition of either high (upper figure, think corn stover or mature small grains) or low (lower figure, think legumes or other forbs) c/n ratio organic materials. Where the c/n ratio of added residue is above 25, microbes digesting the residues must supplement the nitrogen contained in the residues with soluble nitrogen from the soil. During the resulting nitrate depression period, competition between higher plants and microbes would be severe enough to cause nitrogen deficiency in the plants. Note that in both cases, soluble N in the soil ultimately increases from its original level once the decomposition process has run its course. The trends shown are for soils without growing plants, which, if present, would continually remove a portion of the soluble nitrogen as soon as it is released. The carbon-to-nitrogen ratios and immobilization and mineralization are critical components for a farmer. It determines the fertility program and also the cover crops that need to be in either a mix or a single species.

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Microbe Math: (10 minutes or assign as homework) Pose questions to the group about different crops and cover crops planted. What if you planted a mixture of plants? How can you impact the ratios then? (Use a smaller percentage of winter grasses prior to heavy nitrogen-using crops, increase the broadleaves and legumes.)

References

https://open.lib.umn.edu/horticulture/chapter/3-3-roots/

https://extension.okstate.edu/fact-sheets/mycorrhizal-fungi.html#:~:text=Mycorrhiza%2C%20which%20means%20%E2%80%9Cfungus%2D,and%2For%20nutrients%20in%20return.

Lesson Overview

Maximizing Cover

NATIONAL AGRISCIENCE STANDARDS

SS.03.04.	Apply microbiology principles to environmental service systems.
ESS.03.04.01.b.	Assess how the activities of microorganisms in soil affect environmental service systems and ecosystem biodiversity.

NEXGEN SCIENCE STANDARDS

HS-ESS3-1.	Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity
HS-ESS3-2.	Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.
HS-ESS3-4.	Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

Key Concepts

- Why is cover important.
- What different types of cover look like.
- How topsoil interacts with the atmosphere.

Vocabulary

- Erosion
- Living Cover
- Dead Cover
- Water holding capacity
- Crusting
- Mulch
- Residue

Day Eleven

Interest Approach (10 Minutes): Vess Card Activity

Materials: Shovels, locations of different types of management, Vess Card

Activity (20 minutes): Use the VESS score card to dig small 1-foot-deep mini pits. Take a small spade cut along the edge of the pit to pull out and look at. Follow the instructions on the Vess card for scoring. Use a field that has had full tillage year after year, a field that was in no till and a field that is in grass to compare and score. In urban settings look for an area that has had construction recently, a lawn that is mowed very frequently, one that is left to grow and not mown often, a garden that is rototilled and if you can a garden that is using no-till to compare. You could also use a foot path vs. the grass adjacent to it.

Content (15 minutes): Keeping the soil covered year-round will protect it from various threats. Those threats could be loss of water through evaporation, erosion due to rain and wind, and competition from weed species. There are multiple ways to keep soil covered, but typically, maximizing cover refers to either cover crops and/or mulching.

Maximizing cover prevents soil erosion by holding the soil in place and protecting the soil against wind and rain. Keeping the soil covered can conserve soil moisture through increasing water infiltration and reducing evaporation. The less soil is exposed to the sun, the less water will be lost, and the risk of soil crusting will decrease. Soil crusting occurs when there is a breakdown of the structural aggregates from flowing water, rainfall, or freezing and thawing of bare soil. Soil crusting is concerning as it can limit seedling emergence, reduce oxygen diffusion to seedlings, increase water runoff, limit water evaporation and infiltration, and increase wind erosion. Cover crops also help retain nutrients otherwise lost through soil erosion and runoff, improving water quality.

There are two main types of soil cover, living cover and dead cover. Living cover refers to cover crops, and dead cover refers to soil mulching or residue.

Cover crops are one-way farmers can maximize cover on their fields. We have discussed cover crops in previous lessons. What do we remember about the benefits of cover crops providing a living root? (reducing erosion, increase nutrient cycling, nitrogen fixation, increased water infiltration and storage) How might cover crops benefit the top of the soil as well? (look for answers like limiting soil crusting, increased water infiltration, reducing evaporation, keeping the ground shaded, providing a food resource to insects and soil biota)

Quick NRCS review of cover crops: https://youtu.be/NLoEkcbsJLo

Cover crops are living cover and provide ecosystem benefits including reducing erosion, increasing nutrient cycling, and nitrogen fixation. They can also intercept radiation and insulate the soil surface to moderate soil temperatures. Cover crops increase soil water capture and limit soil water evaporation. They do use soil water, which can impact the cash crop and needs to be considered based on the climate, but without them as part of the rotation you will not see improved soil function.

In farming, dead cover is oftentimes the residue left on the field after harvest. This residue will break down on the soil surface and can release nutrients back into the soil. The soil organisms will then further break down those nutrients and make them available for plants to use again.

Mulch is a protective layer of material spread on top of the soil. It helps conserve water and extend water availability. Mulch also protects soil from wind and water erosion, suppresses weeds, and moderates temperature extremes. Areas around the main crop can be mulched to suppress weeds. Soil temperature drives seed germination and seedling emergence. It directly affects plant growth and the activity of soil organisms. The same temperatures we like from 50-90 degrees are the same that soil biota and plants perform best. Nitrification, soil moisture, aeration, and nutrient availability are also impacted by soil temperature. The more the soil is covered the less area exposed to the sun for evaporation. This will allow for water to better infiltrate into the soil profile.

It is important to keep the soil covered because microbial and nutrient activity in the soil is impacted by soil temperature, soil water holding capacity, and extreme weather changes. Uncovered soil will be more susceptible to increased temperature, drought, and weather and erosion threats. This is important to farmers because this will impact the overall growth of their crops in the soil.

Quick videos on residue and residue breakdown:

https://youtu.be/7h6U9s2Hu1Q

https://youtu.be/7h6U9s2Hu1Q

Discussion Opportunity: Break the students into two groups, or break small groups in half, whatever is easier. Have half the students discuss the or list out the benefits of leaving residue on the field at the end of the harvest based on all the information that has been discussed and shown in the video. Have the other students discuss or list out the challenges from leaving residue and the potential problems discussed and shown in the video. Come together in the class setting to list out the pros and cons of residue and open for discussion.

Ultimately, it comes down to the farmer deciding what works best for their rotation, and depending on the microbial activity, the farm's location, or soil temperature, leaving residue may not work for that farmer. There are benefits, but if the cons outweigh the benefits, they won't leave it and could harvest for silage. If they choose to leave it, they could graze it or leave it as residue cover to be planted into.

Teachers are encouraged to demonstrate the rainfall simulator activity today to help save time for tomorrow's lab day. Be sure to prepare tomorrow's lab materials.

Day Twelve

Materials: Rainfall simulator and worksheet; soil samples that different managements *(i.e., bare soil, cover crop planted soil (if planted prior to the start of the unit) and mulched soil) Teachers may also find soil outside that has different management types, such as soil disturbed by construction and soil covered by grass.*

Interest Approach: Midpoint Check-In. Hand each student two sticky notes—one to write their key takeaway from this unit so far and one to write a question they still have about soil health. Students should *not* print their name on the sticky note. Once all students have written on their sticky notes—instruct them to place them under the appropriate category at the front of the room. Teachers should write "What I learned" and "Questions I have" in separate areas at the front of the room for students to stick their sticky notes to.

As students return to their seat, observe the "Questions I have" side first. If students have related questions, arrange them together while reading them out loud. Once arranged, move to the "What I have learned" section. If any of the "What I learned" answers a question from the other side, discuss those first. Leave the sticky notes at the front of the board throughout the lesson. Refer to these questions as you work through the lesson if they align.

Lab activity: *Pass out student worksheet. Instruct students to hypothesize what might happen with each of the samples, given what they currently know about cover on soil.*

References

https://www.sare.org/publications/managing-cover-crops-profitably/benefits-of-cover-crops/

https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5293781.pdf

Lesson Overview

Increasing Biodiversity

NATIONAL AGRISCIENCE STANDARDS

NRS.01.	Plan and conduct natural resource management activities that apply logical, reasoned and scientifically based solutions to natural resource issues and goals.
NRS.01.01.	Apply methods of classification to examine natural resource availability and ecosystem function in a particular region
NRS.01.01.02.b.	Analyze the interdependence of organisms within an ecosystem (e.g., food webs, niches, impact of keystone species, etc.) and assess the dependence of organisms on nonliving components (climate, geography, energy flow, nutrient cycling, etc.)
NRS.01.01.02.	Conduct analyses of ecosystems and document the interactions of living species and non-living resources.

NEXGEN SCIENCE STANDARDS

HS-ESS3-2.	Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.
HS-ESS3-4.	Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

LESSON 5

Key Concepts

- Understanding relationships within the complex food web.
- Understanding how biodiversity is key to a high-functioning ecosystem.
- The use of pollinators and their role in agriculture

Vocabulary

- Food Web
- Trophic Levels
- Autotrophs
- Consumers
- Detritivore
- Biodiversity
- Pollinators
- Apiculture
- Keystone Species
- Nutrient Cycling

Day Thirteen

Material: Paper, colored pencils, PowerPoint, video capabilities

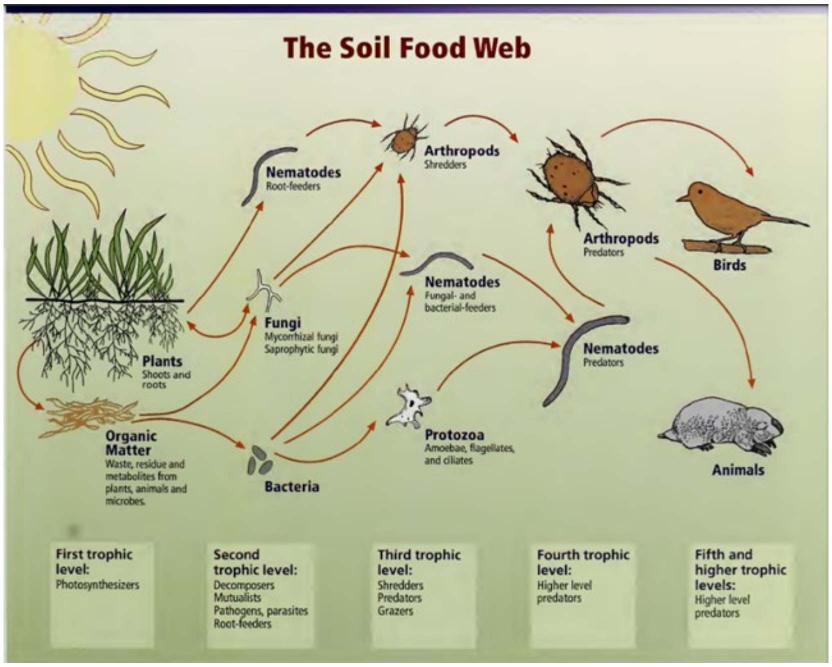
Interest Approach (10 minutes): Ask students to draw their best **food web**. You can also challenge students to make the "biggest" food web in 7 minutes. Students have likely visited this topic several times in other classes.

Content (30 minutes): This lesson is likely to review a lot of aspects, but it will tie into the benefits of biodiversity on the soil. The NRCS definition of **biodiversity** is the variety of life forms within a given ecosystem or farm field. The different life forms include all the plants, animals, and microorganisms that are present. Each life form includes its own unique set of exudates, secretions, or waste products that further contribute to increased diversity. Healthy management systems are full of biodiversity. Increases in diversity can be achieved through various approaches, including plant diversity (through diversified crop rotations and cover crop mixes) and integration of grazing animals (e.g., livestock) into the system. It includes animals living within the soil or microbial diversity, as well as direct additions with biological amendments.

A food web consists of all the food chains in a single ecosystem. Food chains depict the transfer of energy and nutrients as they move through the ecosystem. There are different categories within the food web called **trophic levels**. These trophic levels are **producers**, **consumers**, and **decomposers**. Producers make up the first trophic level. They consist of **autotrophs**, which are organisms that can make their own food and do not depend on any other organisms for nutrition. Most commonly, these are plants. Consumers are the second trophic level. They consist of organisms that need to consume other organisms for energy. Primary consumers are herbivores, as they exclusively consume producers. Secondary consumers are carnivores and omnivores as they consume primary consumers. Tertiary consumers eat secondary consumers. Apex predators are the top consumers that have no other natural predators outside of humans.

Detritivores and decomposers are the organisms that eat nonliving plant and animal remains. These include scavengers such as vultures, fungi, and bacteria that live in the soil. These organisms cycle waste back into the soil, which in turn fosters the growth of autotrophs, starting the whole cycle back over.

Biodiversity supports every level of the food web. Biodiversity supports the habitats for all species at every level of the food web. Each organism can be supported in its unique environment through the creation of ecosystems of all types and sizes. Diversity not only refers to food sources, but also aboveground diversification of plants and animals, as well as microbial diversification underground. Diversification stimulates a host of additional benefits, including breaking disease cycles, providing habitat for pollinators, wildlife, and beneficial predators, and stimulating plant growth.

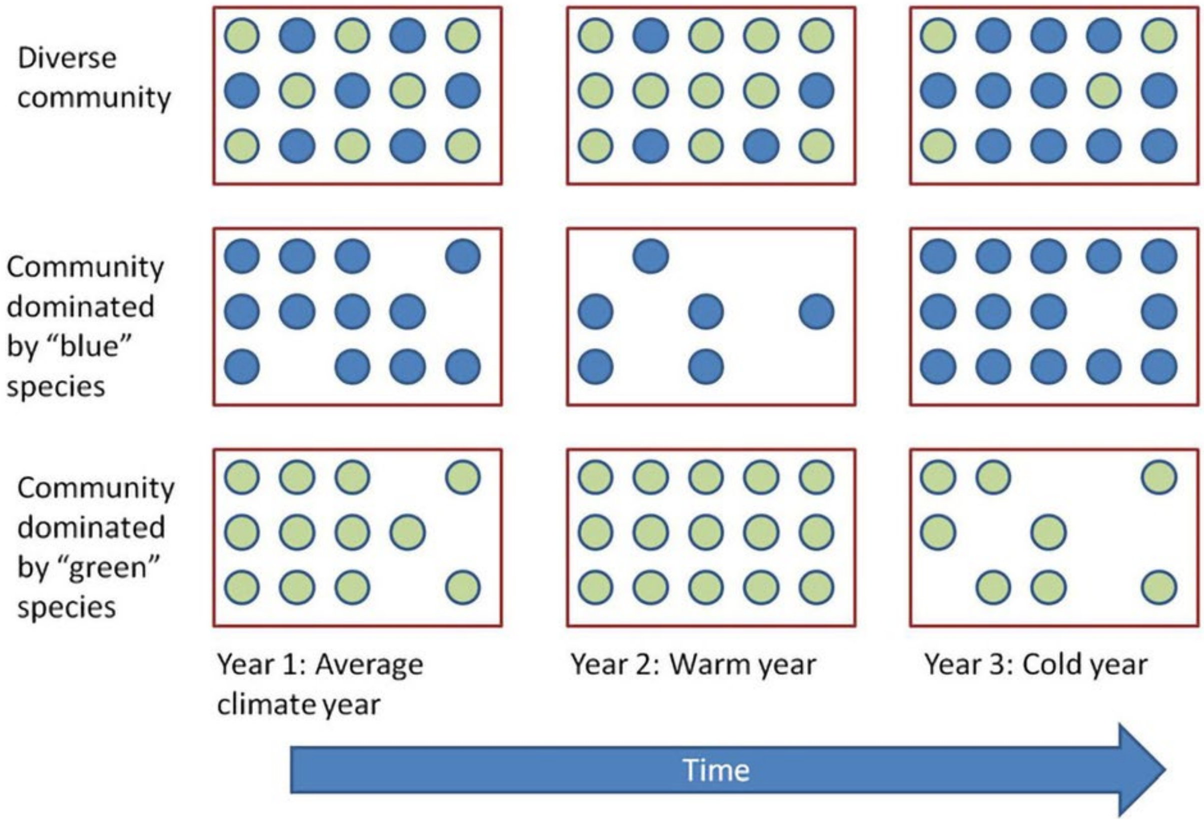


Soil biodiversity is created from the various types of life that exist within and above the soil. This can include bacteria, fungi, earthworms, beetles, ants, and termites. A teaspoon of topsoil typically contains up to 6 billion microorganisms. Soil is the most biologically diverse material on earth.

The soil is responsible for recycling biomass within the food web. Worms, microorganisms, bacteria, and fungi are all responsible for putting nutrients back into the soil. Disruptions within this level of the food web impact the entire ecosystem. This is also true for apex predators. All the organisms within the soil interact with each other through cycles and predator-prey relationships. It's all about eating and being eaten.

Farming with biodiversity can look like rotating between crops grown in the same field, leaving field borders enriched with native grasses and flowering plants, not bulldozing out trees along fence lines or in woody draws, and incorporating grazing animals. This can optimize **nutrient cycling**, improve water quality and quantity, as different crops use and produce different nutrients. Additionally, it can control weeds through the varying competitiveness of crops against different weed species and disrupt pest and/or pathogen lifecycles. Incorporating various crops to cycle nutrients into the soil can help better overall growth of autotrophs. Secondly, greater crop diversity provides more habitats to foster beneficial insects. Insects are key to **pollination**, but specific predatory insect species are also important in mitigating pests harmful to crops. It is important to have all levels of the food web participating in the overall stability of the system. We also need to add diversity to the cover crop mixes we use within rotations; single species or monocultures have less of an impact on above and below ground biodiversity.

Diverse ecosystems lead to better adaptation to changes in conditions. This can include weather changes, diseases, and overall climate change. The greater biodiversity in crops and cover crop mixes, the greater the ability for natural control of pests and disease. This can also include rotating which animals graze on which plots of land, rotational grazing, as well. Introducing livestock into a field can bring in fresh nutrients from their waste and help control weed species. Planting a grazing crop would expand the rotation and letting it grow enough to graze will increase the diversity in the soil microbiome.



Conceptual diagram showing how increasing diversity can stabilize ecosystem functioning

Each rectangle represents a plant community containing individuals of either blue or green species, and the total number of individuals corresponds to the productivity of the ecosystem. Green species increase in abundance in warm years, whereas blue species increase in abundance in cold years, such that a community containing only blue or green species will fluctuate in biomass when there is interannual climate variability. In contrast, in the community containing both green and blue individuals, the decrease in one species is compensated for by an increase in the other species, thus creating stability in ecosystem productivity between years. Note also that, on average, the diverse community exhibits higher productivity than either single-species community. This pattern could occur if blue or green species are active at slightly different times, such that competition between the two species is reduced. This difference in when species are active leads to complementary resource utilization and can increase the total productivity of the ecosystem.

Optional videos

How Wolves Change Rivers

https://www.britannica.com/video/162778/keystone-species-parts-coast-kelp-forest-ecosystem

Day Fourteen

Materials: Video capabilities, PowerPoint

Interest approach (10 minutes): Watch the video: The Power of Pollinators (youtube.com)

After watching the video, instruct students to write for one minute about how agriculture impacts AND is impacted by **pollinators**, such as the bees in the video. Discuss student thoughts as a group.

Content (20 minutes): Pollinators are very important to agriculture. Pollinators move the pollen grains from flower to flower. Over 200,000 animal species act as pollinators, and of those, about 1,000 are hummingbirds, bats, and small mammals (Source: USDA Forest Service). The rest are insects, such as beetles, bees, ants, wasps, butterflies, and moths. What is pollination? According to the Oxford Dictionary, pollination is the transfer of pollen to a stigma, ovule, flower, or plant to allow fertilization. Most plants require the assistance of pollinators to produce seeds and fruit. About 80% of all flowering plants and over three-quarters of the staple crop plants that feed humankind rely on animal pollinators (USDA Forest Service).

In the United States alone, pollination of agricultural crops is valued at 10 billion dollars annually. Globally, pollination services are likely worth more than 3 trillion dollars. More than half of the world's diet of fats and oils comes from animal-pollinated plants (oil palm, canola, sunflowers, etc.). More than 150 food crops in the U.S. depend on pollinators, including almost all fruit and grain crops. The USDA estimated that crops dependent on pollination are worth more than 10 billion dollars per year.

Flowering plants produce breathable oxygen by utilizing the carbon dioxide produced by plants and animals as they respire. However, levels of carbon dioxide in the atmosphere have been rapidly increasing in the last century due to increased burning of fossil fuels and destruction of vital forests—the "earth's lungs." Pollinators are key to the reproduction of wild plants in our fragmented global landscape. Without them, existing populations of plants would decline, even if soil, air, nutrients, and other life-sustaining elements were available. Flowering plants help to purify water and prevent erosion through roots that hold the soil in place, and foliage that buffers the impact of rain as it falls to the earth. The water cycle depends on plants to return moisture to the atmosphere, and plants depend on pollinators to help them reproduce. (USDA Forest Service)

Some farmers seek government assistance to diversify their farms and plant areas where pollinators will be attracted. The Conservation Reserve Program (CRP) is an example of one way the government can provide funds for farmers to plant areas that are attractive to pollinators.

Activity (15 minutes): Let's watch this video (https://www.youtube.com/watch?v=JpPhLj-0Db0) about how a farmer is using technology to diversify the farm and increase pollination. As you watch the video, consider: 1) What technology makes this possible? 2) From an economics perspective, are there benefits to the farm?

Day Fifteen

Materials: Poster board, craft supplies, internet access, Increasing Biodiversity-Pollinator Habitat Activity worksheet, painters' tape (for hanging posters)

Interest Approach (7 minutes): Ask students to take out a piece of paper to journal their thoughts on this question: Yesterday, we discussed pollinators and their importance, specifically within agriculture. Where do you think pollinators fall in a food chain? How about a food web? Why do you think that?

Activity (30 minutes): Dividing students into groups of 2-3, give each group a large (11x17' or poster board) paper. Provide a variety of crayons, colored pencils, markers, etc. A computer may be used to help identify specific pollinators and what plants attract them. Ask students to design a pollinator habitat for your school, home, or community. Use the following as guidance:

1. Identify 3 species of pollinators that they wish to attract.
2. Identify 2 species of plants they would like to plant that would attract EACH of the pollinators (6 in total).
3. List the 4+ benefits of the pollinator habitat on their school, home, and community.

Draw the pollinator habitat and answer these questions on the poster board.

Classroom Walk (8 minutes): Students should present their pollinator habitat to the class at the end of the class period for a classroom walk to view all posters.

Additional Resources

https://www.pollinator.org/pollinators#:~:text=Birds%2C%20bats%2C%20bees%2C%20butterflies,resources%20by%20helping%20plants%20reproduce.

5E Student Lesson Planning Template (nps.gov)

Who Are the Pollinators? | US Forest Service (usda.gov)

https://kx.osu.edu/story/honey-bees-soybean-flowers?utm_campaign=faes_kx_awareness_fy23_extension&utm_source=email&utm_medium=email

References

https://education.nationalgeographic.org/resource/food-web/

https://www.environment.nsw.gov.au/topics/land-and-soil/soil-degradation/soil-biodiversity#:~:text=Soil%20biodiversity%20is%20the%20variety,up%20to%206%20billion%20microorganisms.

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LESSON 5


SHAWN LINEHAN

Lesson Overview

Incorporating Livestock

NATIONAL AGRISCIENCE STANDARDS

AS.01.02.	Assess and select animal production methods for use in animal systems based upon their effectiveness and impacts

NEXGEN SCIENCE STANDARDS

HS-ESS3-4.	Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

Key Concepts

- How livestock impacts the environment
- Grazing livestock for soil health
- What considerations are needed to add livestock to land

Vocabulary

- Manure
- Stocking rate
- Organic matter
- Over-grazing

Day Sixteen

Materials: PowerPoint, optional: Determining Carrying Capacity and Stocking Rates for Range and Pasture in North Dakota R1810 (usda.gov)

Interest Approach: To start the lesson, ask students to write for 2 minutes about owning an animal. This could be a pet they have themselves, or what they think it might be like to own an animal. What things would they need to own this animal? What work goes into owning this animal? Where would they keep this animal?, etc.

LESSON 6

Content: Animals have been a part of the land for centuries. Back before settlers moved to America, large buffalo and antelope herds grazed the land. Over time, people have inhabited the land that was once home to grazing animals. For years, farmsteads were home to various animals to meet the farm family's needs. However, as pressure increased on farmers to provide more food, fiber, and fuel to everyone, farmers became more specialized in growing certain crops, such as corn and soybeans, as seen in the Midwest, and have often stopped raising animals as well. Today, we will explore why and how livestock can be beneficial to the land and some of the barriers to having livestock.

Livestock deposit **manure** while grazing, and the benefits of manure on cropland have been known for thousands of years. Research has verified and quantified the impacts of manure. For example, Douglas Edmeades reviewed long-term comparisons of manure and fertilizer and showed that both have very large effects on soil productivity as shown by crop yields. Also, adding manure to soils was shown in these studies to increase **organic matter** and soil microorganisms; increase phosphorus, potassium, calcium, and magnesium in topsoils; and increase nitrate nitrogen, calcium, and magnesium in subsoils. Manured soils were also shown to be more porous and have lower bulk density (a measure of compaction) and higher aggregate stability than fertilized soils (2003). At the levels used in these studies, there was no significant difference in crop yields between fertilized and manured soils. However, as prices of fertilizer rise, economics may favor the use of manure, particularly if that manure is applied directly by the animals as they are grazing in a controlled way. (Integrating Livestock and Crops: Improving Soil, Solving Problems, Increasing Income–ATTRA–Sustainable Agriculture (ncat.org) In many cases, manure can be found cheaply or even free to farmers for their fields from livestock feedlots, hog and poultry facilities, and other places that must remove animal waste for animal health reasons.

Animals can solve problems for farmers by doing what they do naturally - eating. Grazing animals, particularly sheep and goats, can eat weeds that can be a nuisance in cropping fields. By eating the weeds, the animals can also remove habitat and larvae for pests, such as the alfalfa weevil and wheat sawfly. Livestock can also consume over-ripe vegetables and fruit and reduce waste. In Kansas, farmers often also use cattle to graze corn fields after harvest to reduce volunteer plants in the next crop season.

Additionally, livestock can provide farmers with an additional revenue stream by selling their offspring, meat, eggs, or fiber. Livestock can also provide a service; for example, goats have been used to clean up brush and woody encroachment areas. In some cases, farmers can also save money on fertilizer, pesticides, and herbicides because livestock can supplement or reduce the need for these inputs.

One important part of having livestock in your cropping system, along with your pastureland or range, is incorporating rest-time for the land to recover from grazing.

That rest is critical to plant growth, which requires around 45 days before you re-graze the plants to encourage healthy soil.

Leaving an adequate amount of cover on the soil surface is critical from an erosion standpoint and to reduce carbon and moisture loss. You need at least 75% of the soil to be covered. This will be dead cover and or living cover to protect the soil surface for microbial communities and to feed them for nutrient cycling for your following crop. Example of grazing over grazed on the left, ungrazed on the right. What are some things that can be done to reduce the amount of over-grazing?

Example of grazing over grazed on the left, ungrazed on the right. What are some things that can be done to reduce the amount of over-grazing?

Stocking rate is a large component of grazing livestock. It is the number of specific kinds and classes of animals grazing or using a unit of land for a specific time period. If a person exceeds the stocking rate, animals will overgraze the area and create additional problems associated with bare soil. Farmers and ranchers must take many factors into consideration when determining how many livestock can be on a piece of land, including, but not limited to: type of animal, class of animal (lactating, breeding, etc), soil type, type of forage and nutrient density, water, and rainfall.

But, if livestock are so beneficial and stocking rate can be managed, why don't all farmers have livestock? A similar question can be asked as to why not all people have pets. (Return to interest approach if needed. Some farmers do not enjoy animals, nor have time to care for them. Cost is also a major factor in acquiring livestock. Not just the cost of the animal, but other costs as well. What other costs are involved in raising livestock?

(Start a list at the front of the room. Anticipate and guide students through the following list: fencing, water, housing, feed when grazing is not available, medical costs, etc.)

Bonus Material: Read & complete activities on Determining Carrying Capacity and Stocking Rates for Range and Pasture in North Dakota R1810 (usda.gov)

Days Seventeen & Eighteen

Materials: Case studies, highlighters, computers with internet for research, Incorporating Livestock Activity worksheet

Interest approach: Use the case studies (Integrating Livestock and Crops: Improving Soil, Solving Problems, Increasing Income – ATTRA – Sustainable Agriculture (ncat.org)), pair students up. Each pairing should have 2 different case studies- 1 for each student. Ask students to read their case study, highlight essential information, and share with their partner at the end. Every student will then have essential information from 2 case studies on incorporating livestock.

Students will complete research on different types of livestock for the next project. It is recommended to spend this class period researching and answering questions, and one class period allowing students to present their results to the class.

Animals for research include: Goats, Sheep, Cattle, Chickens, Hogs

Lesson Overview

Urban Agriculture

NATIONAL AGRISCIENCE STANDARDS

PS.01.02.	Prepare and manage growing media for use in plant systems.

NEXGEN SCIENCE STANDARDS

HS-ESS3-2.	Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.
HS-ESS3-4.	Evaluate or refine a technological solution that reduces the impacts of human activities on natural systems.*

Key Concepts

- Understand what agriculture looks like on a small scale.
- Understand the soil health difference for urban agriculture.
- Understand how urban agriculture can address food access issues and support community.

Vocabulary

- Urban
- Small Space Farming
- Hydroponics
- Raised Beds
- Container Gardening
- Community Garden
- Farmers Market
- Soil Contamination

Day Nineteen

Interest Approach: Turn to your neighbor, does either of your families grow any plants at home? If not, do you know of any family members who grow plants at their house?

Content: Urban agriculture has been around for a long time. During WWI, there were War Gardens, and during WWII, they were rebranded as Victory Gardens. The Victory Garden program was intended to increase the production of fresh fruits and vegetables in the community. It encouraged storage and preservation of surplus, and for the goods to be shared within the communities. Community gardens were established for those who could not have a home garden in their urban space. The goal of these wartime gardens was to free up resources, redirecting them from agricultural to war efforts. In 1939, more than $200 million worth of vegetables were grown in 4.8 million farm home gardens. In 1944, 18.5 million gardeners took part in Victory Gardens, supporting 40% of the nation's fresh vegetables during that time.

Today, urban means belonging to or relating to a city or town. Urban agriculture allows for the development of environmental, economic, and social benefits to surrounding communities. The popularity of farmers' markets has greatly increased the local availability of produce, especially in communities where residents do not have access to healthy produce

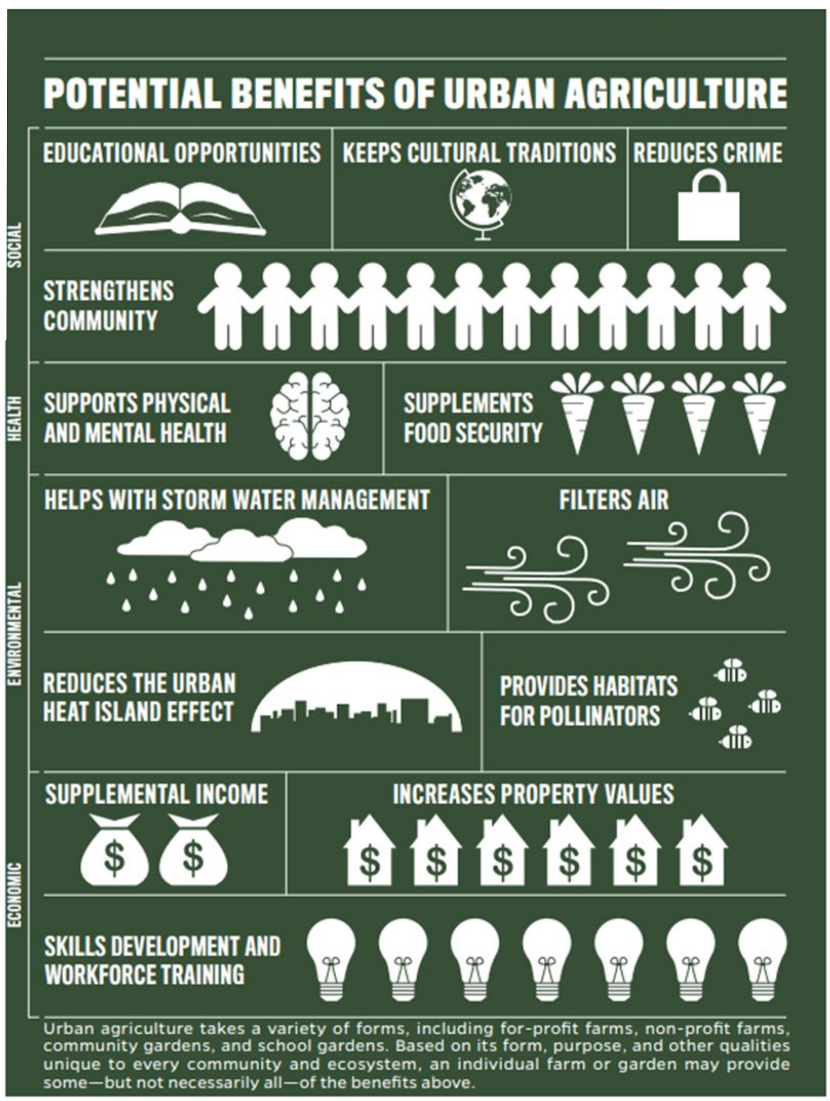

Image credit: Maya Braunstein

There are many potential benefits of urban agriculture. On top of the educational and environmental benefits, there are community benefits. In areas with limited access to grocery store produce, it can provide access to fresh food. It can be a place of community gathering as well as providing supplemental income for those who can sell produce in their community or at farmers markets.

Just like conventional agriculture, urban agriculture must consider the soil. Unlike conventional agriculture, urban agriculture often deals with higher levels of heavy metals and/or lead contamination. This is due to the former industrial use of land in urban spaces. Additionally, urban soils can vary even more than rural ones. They can also have issues from compaction from machines and construction. Often, construction removes the topsoil layer. This contamination cannot be remediated through nutrient cycling, and many times it is unsafe to grow directly in the soil in urban spaces. This is why urban agriculture often takes place in containers or raised beds. Other areas of urban land and green spaces have been successfully managed as gardens for a long time.

PROPERTIES OF URBAN SOILS

PHYSICAL PROPERTIES	
Parent materials	Many urban soils are formed from human-transported materials, such as fill, in all or part of the soil profile.
Coarse fragments	High concentrations of coarse fragments are common in many urban soils.
Horizons	Horizons may be homogenized, truncated, or have weak development. Urban soils may also be missing particular horizons, such as A horizons or topsoil.
Spatial Variability	Urban soils tend to have high levels of both horizontal and vertical variability in soil properties.
CHEMICAL PROPERTIES	
Heavy metals & organic compounds	Increased potential for soil contamination by heavy metals and organic compounds
Nutrient content	Variable nutrient content. Nutrients may be low in soils that have not previously been used for gardening.
pH	Variable pH. Can have alkaline pH from incorporation of cement-based building materials.
BIOLOGICAL PROPERTIES	
Organic matter and carbon	Variable. Can be extremely high as well as very low, based on site management history.

https://directives.nrcs.usda.gov//sites/default/files2/1716469390/TN%20470-SH-02%20Basics%20of%20Urban%20Soil%20Health.pdf

There are a variety of characteristics of urban soils. They vary by location, but also by the type of activities that have occurred there. Urban soils can range from long-term green space to highly altered construction zones. Depending on the horizontal and vertical zones in the soil, there can be stark differences. Topsoil has been removed and transferred across different locations within cities. This greatly impacts the soil horizon depending on the activities that have occurred on that piece of land.

FREQUENTLY ENCOUNTERED SOIL RESOURCE CONCERNS IN URBAN AREAS

RESOURCE CONCERN	MANAGEMENT HISTORY ASSOCIATED WITH RESOURCE CONCERN
Compaction	• Use of heavy machinery for construction and demolition of buildings • Concentrated areas of heavy foot traffic
Concentration of salts or other chemicals	• Soil contamination by heavy metals and organic compounds due to industrial land use and use of industrial products • Use of salts on roads
Organic matter depletion, soil organism habitat loss or degradation, and related resource concerns	• Sites with recent construction or demolition activities • Sites where topsoil layer has been removed • Sites where soil has been covered with inorganic materials or kept bare
Unsuitable material and soil sealing	• Soil surface is dominated by anthropogenic soil property (e.g., coarse fragments) that creates constraints to intended land uses • Soil sealing describes sites where soil has been covered with an impervious surface (e.g., asphalt)

Compaction is a frequent problem in urban soils because there is more heavy machinery that moves across them for construction purposes. Due to the location and type of use of that soil or what has been on that property previously, there can be salts or other chemicals. The salt from the road can run off into the soil, making it difficult for plants to grow, and chemicals that can be dangerous to grow in. Depending on what has happened to that soil over time, there could be little to no organic matter or even topsoil. Also, depending on the site, there could be more impervious materials than pervious. Meaning, there is little water infiltration or no place to put plants into the ground. This is often why urban agriculture occurs in raised beds where soil is brought in, and plants are grown above the surface of the ground.

The main way people are exposed to contaminated soils is direct ingestion of the soil by breathing in dust or ingesting soil on their hands, small children eating soil, etc. Simple methods for reducing exposure and risk are to "Cover bare soil" with mulch or living plants (mulch unused soil), and as you mention, use constructed raised beds with imported materials.

Activity: Use your local website to do a farmers market search to see how many farmers markets are near you.

http://ohioproud.org/farm-markets-all/farmers-market-search/

https://www.fromthelandofkansas.com/market/list

Day Twenty

Interest Approach: Review Conservation Practices for Urban Agriculture

Materials: Tabletop hydroponic garden and seeds, PowerPoint, video capabilities

There are multiple ways to address urban agriculture resource concerns:

USDA NRCS CONSERVATION PRACTICES FOR IMPROVING SOIL HEALTH AND ADDRESSING RESOURCE CONCERNS IN URBAN SOILS

	RESOURCE CONCERN							
PRACTICE	CPS code	Concentration of Salts or other Chemicals	Compaction	Soil Organic Matter Depletion	Soil Organism Habitat Degradation	Aggregate Stability	Unsuitable Material/Soil Sealing	Soil Health Principles
Raised Beds	812	X					X	1, 3
Mulching	484			X				1, 2, 3
Soil Carbon Amendment	336			X	X	X		2, 3
Cover Crops	340		X	X	X	X		2, 3, 4
Conservation Crop Rotation	328			X	X	X		2, 3, 4
Reduced Tillage	345			X	X	X		1, 2, 3
No Till	329			X	X	X		1, 2, 3
Conservation Cover	327		X	X	X	X		1, 2, 3, 4
Hedgerows	422			X				1, 2, 3, 4
Nutrient Management	590			X				1, 3
Low Tunnels	821				X			2, 3, 4
Irrigation	441 & 442			X	X			2, 3

* Soil Health Principles referenced in table are (1) minimize disturbance, (2) maximize cover, (3) maximize biodiversity, and (4) maximize continuous living roots. Xs mark the resource concerns that are directly addressed in the conservation practice standard (CPS) documents.

Review the chart and discuss what has been covered in the curriculum so far. This would include conservation cover, mulching, cover crops, crop rotation, tillage, and nutrient management. There are many similarities to soil health management in urban agriculture, even if the challenges to the soil are different to start out with.

Urban agriculture can look like patio gardens in gallon tubs and raised beds, rooftop gardens, hydroponic productions, backyard gardens, or community gardens in a vacant city lot. Zoning can be an issue within urban farming. Most cities have strong restrictions on raising animals within the city for production purposes, which can limit urban farming to plant production.

Container gardening uses various containers to grow plants. There are some basic considerations when considering container gardening. These include space, water source, sunlight, drainage, and container material. Within space restrictions, it is also important to consider north-south vs. east-west locations to ensure eight hours of sunlight; a water source that is close to where the plants will be grown; and drainage for plants within containers or raised beds. The material of the container or bed is also extremely important for growing food items. Treated lumber is durable but has chemicals that can leach into the soil and be unsafe. Water access is also key to urban agriculture production. Vacant lots may not have water access established, and treated water is not ideal for plant use.

There are many types of containers that can be used in container gardening, and space oftentimes determines the type of container that will be used. Raised beds are considered another type of above-ground container, but they will take up additional space. Some pros of raised beds include ease of use, overcoming physical limitations of stooping over, fewer pests, different styles, and the ability to be filled with soil if there are soil concerns at the location. The material the raised bed is made from needs to be considered. The different woods versus treated or untreated wood will have different life expectancies. Using a plastic liner versus metal or plastic beds can also impact the soil and life expectancy of the bed.

Hoop houses or high tunnels are used to extend the growing season and are typically seen in fruit and vegetable growing. They are passively ventilated, heated by solar, and can hold heat and humidity. They are a more affordable option compared to a greenhouse, as the structure is not as permanent. The controlled environment can be beneficial for increasing productivity and consistency of crops. Management of crops in a high tunnel will differ from that in a field or even a raised bed. It will not get as cold inside the hoop house; daily watering is necessary, as there will never be direct rainfall, and the humidity in the structure can impact the plants.

Community gardens can be used to provide local produce and a place to grow food for the neighborhood. These are usually in local spaces and use a combination of in-ground planting, raised beds, and container gardening. Many places are now implementing rooftop gardens, which are often designed using raised beds, when there is no central location available in a city. Schools are also implementing more community growing spaces to teach students about growing their own food.

Hydroponics is the technique of growing plants in a water nutrient solution instead of soil. View the virtual field day: Hydroponic Greenhouse—Virtual Field Day—University of Florida, Institute of Food and Agricultural Sciences—UF/IFAS

Activity: Review the virtual field day videos, soilless systems, containers, and floating hydroponic garden. Allow for discussion on the pros and cons of a system like this. Expect answers like "good if you cannot access soil, bad because it is expensive to implement and feed water and nutrients into." Options for this lesson include planting a hydroponic garden using a kit or planting seeds into various containers. Discuss the similarities and differences between this system and the systems observed.

Day Twenty-One

Interest Approach: Turn to your neighbor, have you ever seen farm animals in a city? What animals do you typically see in the city? Have or can these animals be farm animals?

Urban agriculture livestock can range from raising bees for honey to having a lot with cows or goats. Most communities regulate residential livestock through zoning laws and development codes. Typical urban livestock includes chickens, ducks, bees, rabbits, and sometimes goats. The largest limitation for urban livestock, outside of zoning regulations, is space restrictions. Close neighbors mean that individuals are responsible for limiting nuisance situations. Additionally, challenges such as feed supply and lack of processing facilities can limit someone's ability to successfully farm livestock.

Considerations for chickens include space limitations, purpose of the chicken, egg or meat, and number of chickens to include. The different breeds of chicken can serve multiple purposes. Additionally, different chicken breeds may respond to different climates. There are also chickens that have different temperaments if they are going to be interacted with, family or children, versus left out in the pasture alone more often.

Rabbits are another common livestock in urban agriculture. Rabbits are popular because they are quiet, do not require much room, and can be used for multiple purposes. Rabbits can be used for fur, manure, as pets, and for their meat. Unlike other manures, rabbit manure does not require composting before use on the soil. It is easy to spread and use on a small scale, unlike larger hoofed animals.

Rabbits are very versatile when it comes to their diets. Hay and pellet feed are typically used for rabbit feed, but dandelions, clover, and other things can also be fed to them. Like other animals in the rodent family, rabbits constantly need to chew on things to keep their teeth from growing too long. Bark and branches are great options for rabbits to chew on.

Bees are a common livestock animal. There is evidence that the relationship between humans and bees is 17,000 years old. There are 4,000 native bees in North America, but honeybees are most discussed, even though they are not native to North America and were imported from Europe. The technical term for beekeeping is Apiculture. Honeybees must consume 17-20 points of honey to biochemically produce a pound of beeswax. The average honeybee will only produce up to 1/12th of a teaspoon of honey in its lifetime, which is why we see populous colonies of up to 40,000 or 60,000 bees. Honey is created as bees collect flower nectar and store it in the honeycomb. The nectar is broken down into simple sugars. Evaporation causes the nectar to become honey. An average hive will produce about 55 pounds of surplus honey a year.

Bees are kept in hives, and these hives can vary greatly in size. Modern beehives have multiple layers. There is a hive cover, which covers the top and sides of the hive. The inner cover, which creates an insulating air space. Shallow supers, for surplus honey storage. The queen excluder keeps the queen separated so her eggs are not laid in the honey super. Hive bodies are brood chambers where the queen will lay her eggs and raise the brood. There is a bottom board that insulates the bottom of the hive. Typically, there is a stand to keep the hive off the ground as well.

Depending on the areas and zoning rules, some people can have larger livestock such as sheep, goats, and cows. Their needs in urban agriculture may include finding a reliable feed source, fencing, an area for the animal, nuisance complaints from noise or smell, and shelter options. The needs of larger livestock can be more difficult to meet in an urban setting, which is typically why poultry, rabbits, and bees are more frequently seen in urban areas. Typically, for cows, 1.5-2 acres is needed to feed a cow-calf pair for up to a year, and that can be challenging to acquire in an urban setting. Pigs need about 8 square feet per pig, which is not a lot of space; however, pigs will root and can significantly change the landscape of where they are kept. Goats typically need 200 square feet each. A sheep will need about half an acre to graze.

Optional Activity: Polycultures: Food where we live. https://www.youtube.com/watch?v=rq1fp_ioBGM 54-minute film from Cleveland and Northern Ohio. Covered a lot of social considerations related to urban agriculture, as well as larger issues with the American food system.

USDA

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Teachers observing a no-till planter during a pilot teacher training event.

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