Food and Agriculture Center for Science Education

UNIT STARTER TOOLKIT: SOIL

Life Science: Ecosystems

Middle School

American Farm Bureau Foundation for Agriculture

ABSTRACT

Soil is a living ecosystem, full of bacteria, fungi, and other microbes, and it supports plant, animal, and human life. The capacity for soil to support various living organisms and systems, including agriculture systems, is based on characteristics of the soil, and in many cases, the management of the soil as a complex resource. For example, several hundred different soil series can be found in Washington and their unique characteristics impact their uses such as for timber production, livestock grazing, or crop production and related management such as rotational grazing and irrigation across the state.[26] The organisms and ecosystems that rely on suitable soil for life also contribute to the bioactivity of soil by aiding the conversion of energy and nutrients. For example, cattle can have a symbiotic relationship with many different soils in Washington; however, thoughtful management of the relationship based on knowledge of ecological interactions between cattle and soil ecosystems must be implemented to ensure the symbiosis is sustained.

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Suitable Soil

Introduction

This document describes agriculture-related phenomena and problems that could serve as drivers for science or agriculture instruction. The ideas in this document could serve as anchors driving a coherent sequence of lessons, investigative phenomena that help illustrate part of a larger anchor phenomenon or problem, or as the focus of transfer tasks. When used in one of these three ways, the process of explaining these phenomena or solving these problems would support student learning or showcase their learning connected to the Next Generation Science Standards (NGSS) and similar standards based on the [Framework for K–12 Science Education].

What are Phenomena and Problems?

Student learning experiences are more coherent and engaging when students are focused on figuring out something in the real world or solving a problem that is meaningful to them as opposed to when they are simply told to memorize facts.

Phenomena are observable events that students can see in the world, wonder about, and then figure out using their scientific knowledge (e.g., mitosis). Therefore, explaining the phenomenon gives students a reason to learn. Likewise, engineering problems are those that can be solved using scientific knowledge along with engineering principles. Problems — such as sick cattle — are types of phenomena, so solving the problem often involves figuring out what causes the problem in the first place (e.g., microbes).

Phenomena and problems can be used in many different ways in instruction but are introduced before learning takes place in order to focus the learning and give it a purpose. Instruction therefore often begins with students' questions about a phenomenon or problem and ends when students have figured out the phenomenon or solution to the problem. Although a goal of science instruction is to help students develop explanations about the world, explanations themselves (e.g., cells divide through mitosis, producing more cells and allowing animals to grow) are not phenomena, as they are not observable.

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To learn more about using phenomena and problems in instruction, including the central role of student questions, see the resources below:

- https://www.nextgenscience.org/phenomena
- http://stemteachingtools.org/brief/28
- https://sites.google.com/site/sciencephenomena/criteria

Phenomena Outline

Suitable Soil

<table>
<tr>
<td>Phenomenon/Problem:
Soil is a complex resource that is fundamental for all life, but not all soil is suitable for all life.</td>
<td>Stimuli:
How will students experience and/or observe the phenomena/problem?
Use Soil Profiles found on this <u>website</u>
</td>
</tr>
<tr>
<td colspan="2">Related Phenomenon/Problems:
There are many mutually beneficial interactions between cattle and soil.</td>
</tr>
</table>

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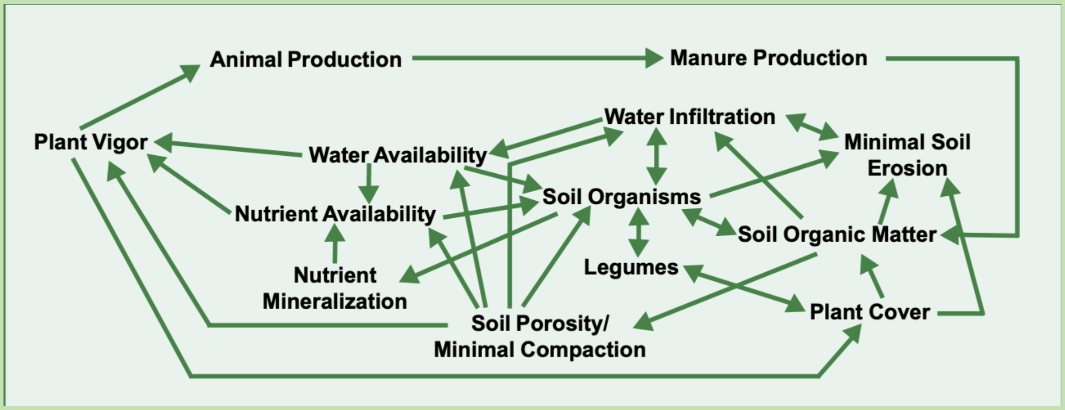

"Healthy plant growth provides plant cover over the entire pasture. Cover from growing plants and plant residues protects the soil against erosion while returning organic matter to the soil. Organic matter provides food for soil organisms that mineralize nutrients from these materials and produce gels and other substances that enhance water infiltration and the capacity of soil to hold water and nutrients."
Nutrient Cycling in Pastures Link

Considerations for Instructional Design:

- Students are introduced to soil types and agricultural production.
- The interaction of humans, animals and soil is shown through example.
- Students gain understanding for the scientific reasons for the phenomena.
- Additional examples are given of how the phenomena appears in the world.
- Students develop scientifically based explanations for the phenomena.

Explanation:

Soil contains living organisms that when provided the necessities of life - food, shelter, and water - perform functions required to produce food and fiber. Healthy soil gives us clean air and water, bountiful crops and forests, productive grazing lands, diverse wildlife, and beautiful landscapes. A healthy soil effectively supports plant growth, protects air and water quality, and ensures human and animal health. The physical structure, chemical make-up, and biological components of the soil together determine how well a soil performs these services.

Soil has both inherent and dynamic properties or qualities. Inherent soil quality is a soil's natural ability to function. For example, sandy soil drains faster than clayey soil. Deep soil has more room for roots than soils with bedrock near the surface. These characteristics do not change easily. Dynamic soil quality is how soil changes depending on how it is managed. Management choices affect the amount of soil organic matter, soil structure, soil depth, and water and nutrient holding capacity. Understanding soil health means assessing and managing soil so that it functions optimally now and is not degraded for future use. By monitoring changes in soil health, a land manager can determine if a set of practices is sustainable. For Example, disturbance in soil is an event, or its change in intensity or frequency, which alters the structure or functional status of an ecosystem. Examples of disturbances that can affect soil include drought, fire, harvest, tillage, compaction, overgrazing, or the addition of pesticide - which over time can affect soil health and it's ability to support the necessities of life. There are also management practices that improve soil health and structure, examples include crop rotation, sustainable grazing and managing erosion.

It is essential to protect and restore soil, as soil is fundamental for all life, but not all types of soils support all types of life. The United States Department of Agriculture classifies soil into 12 categories, called "orders." Each order represents specific soil characteristics - Each order is based on one or two dominant physical, chemical, or biological properties that differentiate it clearly from the other orders. Different types of soil may be better suited for different types of use - forestry, crop production, grazing, etc.

The state of Washington is home to ten of the twelve soil orders! For example, the highly productive Mollisols of the Palouse hills in eastern Washington support remarkable vegetative growth. Rainfall decreases as one moves west from the eastern edge of the Palouse, resulting in less plant growth and accumulation of organic matter. Soils under cultivation in the western Palouse and Columbian Plateau include Aridisols, light colored desert soils. All types of soil are important, and productive, but in different ways and the quality of the soil can be highly affected by the management of the soil. For example, properly grazing by cattle can increase soil biodiversity and its ability to support different types of life.

Student questions about this phenomenon/problem that could be instructionally productive:

Soil:

- What are the characteristics of soil ecosystems in Washington?
    - There are living things in soil!?!
    - What are the living things in soil?
    - What does soil look like under a microscope?
    - Is soil the same everywhere in the world?
- What does soil do?
    - Potential student questions in route to this essential question:
        - Is soil the reason that some plants die?
        - How does soil work?
- What does it mean for soil to be suitable for growing different things?
    - Potential student questions in route to this essential question:
        - Do different plants and animals need different things from soil?
- How do management decisions impact soil health?
    - Potential student questions in route to this essential question:
        - Can people make soil better or worse?
        - What else does soil's health impact?

Grass/Rangeland

- What are the soil characteristics of grass/rangeland biomes in Washington?
    - Potential student questions in route to this essential question:
        - What does "grass/rangeland" mean?
        - What does "grass/rangeland" look like?
        - Is there "grass/rangeland" in Washington?
        - What is the soil in a "grass/rangeland" area like?
- What patterns of ecological interactions are typically found in Washington grass/rangelands?

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- Potential student questions in route to this essential question:
  - What are ecological interactions?
  - What are examples of ecological interactions I am familiar with?
  - How do grass/rangelands in Washington support human life?
    - Potential student questions in route to this essential question:
      - Do “grass/rangelands” matter to me?
  - How do grazing cattle impact soil health in Washington grasslands?
    - Potential student questions in route to this essential question:
      - What do cattle need to survive?
      - What do I know about nutrient cycles?
      - How are cattle part of the soil nutrient cycle?
      - Can cattle be good for soil?
      - Can cattle be bad for soil?
      - Can soil be good for cattle?
      - Can soil be bad for cattle?
  - Can technology increase the beneficial interactions between grazing cattle, western grass/rangelands, and societal needs?
    - Potential student questions in route to this essential question:
      - Are there jobs that work with soil?
      - Are there people who know a lot about soil? Why?
      - How does soil impact me?
      - Do humans impact soil?
      - Can soil die?
      - What can I do with soil?

Explaining the phenomenon/problem or related phenomena could lead students toward developing the following DCIs:

- MS-LS2-2
    - LS2.A: Interdependent Relationships in Ecosystems
        - Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these ~~competitive~~, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared. (MS-LS2-2)
    - LS2.C: Ecosystem Dynamics, Functioning, and Resilience
        - Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health. (MS-LS2-5)
    - LS4.D: Biodiversity and Humans
        - Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on ~~— for example, water purification and recycling~~. (secondary to MS-LS2-5)
- MS-ESS3-4
    - ESS3.A: Natural Resources
        - Humans depend on Earth's land , ocean, atmosphere, and biosphere for many different resources. Minerals, freshwater, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. ~~These resources are distributed unevenly around the planet as a result of past geologic processes~~. (MS-ESS3-1)
    - ESS3.C: Human Impacts on Earth Systems
        - Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) on different living things. (MS-ESS3-3) Typically as

human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise. (MSESS3-3), (MS-ESS3-4)

- ESS3.D: Global Climate Change
  - Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding ~~of climate science, engineering capabilities, and other kinds~~ of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities. (MS-ESS3-5)

Notes about relevance and authenticity (funds of knowledge, interests, identity) Why might students be engaged?

Resources/References:

Resources:

- "The online Soil Biology Primer is an introduction to the living component of soil and how it contributes to agricultural productivity and air and water quality. The Primer includes chapters describing the soil food web and its relationship to soil health and chapters about soil bacteria, fungi, protozoa, nematodes, arthropods, and earthworms."
- Washington Soil Atlas "features many soils from throughout Washington State. It has been prepared to assist readers develop an understanding about the variability of Washington soils and as an aid to further the reader's knowledge of soils. The intent of this atlas is to present some of the different soils mapped and correlated in Washington and to demonstrate how their unique characteristics impact their use and management. Both physical and chemical properties have dramatic impacts on a soil's use and/or management. This atlas only presents brief comments regarding their limitations that impact management but much more information is available from the Natural Resources Conservation Service. Complete information on the soils in Washington State is available

online using the Web Soil Survey tool at: http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm "

- The Twelve Orders of Soil Taxonomy Poster
- Web Soil Survey (WSS) "provides soil data and information produced by the National Cooperative Soil Survey. It is operated by the USDA Natural Resources Conservation Service (NRCS) and provides access to the largest natural resource information system in the world. NRCS has soil maps and data available online for more than 95 percent of the nation's counties and anticipates having 100 percent in the near future. The site is updated and maintained online as the single authoritative source of soil survey information. Some how to use the WSS instructions: link."
- National Commodity Crop Productivity Index - Washington "The National Commodity Crop Productivity Index (NCCPI) is a model that uses inherent soil properties, landscape features and climatic characteristics to assign ratings for dry-land commodity crops such as wheat, cotton, sorghum, corn, soybeans and barley."
- Published Soil Surveys for Washington

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Learning Sequence Prior Knowledge

<table>
<tr>
<td>Foundation
What prior knowledge is crucial as a foundation for the learning sequence?</td>
<td>Terms:

An ecosystem
is a community of organisms interacting with their physical environment.
A biome
is a large area of land comprising plants, animals, and other organisms that are adapted to a specific climate and terrain. Aquatic, grassland, forest, desert, and tundra are the five major biomes found across the globe.
Grazing
is an agricultural practice in which livestock consume vegetation in open areas such as grasslands to convert human inedible food (grass) to human-edible food such as meat.
Grassland
means land on which the vegetation is dominated by grasses, grass-like plants, shrubs, forbs, and rangelands.
Areas of study:
Ecology, a branch of biology, is the study of the relations of living organisms to one another to their physical environment; therefore, ecologists often study ecosystems and biomes.
Conservation ecology, a branch of ecology, is the study of biodiversity with an emphasis on conservation and restoration methods to address declining global biodiversity and natural resources.
Soil ecology: The study of relations between soil organisms and
</td>
</tr>
</table>

	between these organisms and their soil environment.
	
	Sense-making
	• Students will need to apply foundational knowledge of ecology and conservation ecology to 1) make sense of grassland ecological interactions explored in this unit, and 2) accomplish the Performance Expectations (PE) of this unit which are:
	  ○ Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.
	  ○ Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

Common Student Ideas & Misconceptions *Identify potential misconceptions and/or ideas students may bring into the learning sequence.*	Ideas • Students may be familiar with challenges between scientific understanding of ecosystems and human's management of ecosystems. • Students may be familiar with non-human impacts on Earth's ecosystems and how those impact both the ecosystems and human life. Misconceptions • Links between soil health and grazing cattle on grasslands may be assumed to be direct and/or simple if the complexity of interactions between organisms and their environment are not explored. Physical changes to soil health and grasslands may be assumed to be irreversible though this is not always the case.

Pillars of Agriculture	**The relationship between agriculture and the environment** will be explored, particularly relating to 1) land and water stewardship, and 2) environmental decision making. ● Learners will discover how natural resources are used and conserved by farmer's decisions when grazing cattle. **The relationship between agriculture and food, fiber, and natural energy** will be explored, particularly relating to cattle grazing production methods. ● Learners will observe cattle grazing practices such as rotational grazing and data-driven carrying capacities which demonstrate farmers and ranchers considering how their actions affect the environment and cattle nutrition.

5E Model

Learning Target	Science and Engineering (SEP) Crosscutting Concepts (CCC) Disciplinary Core Ideas (DCI)
Essential Questions	These are suggested questions that you, as the teacher, can ask to get students thinking about the phenomena.
Activity	This is a suggested activity that you, as the teacher, can use to help students meet the learning target. You may find maps of other states here: https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm
Resources	These are suggested resources that you, as the teacher can adapt to help students meet the learning target. We encourage you to bring in speakers, connect with local cattle resources such as extension agents, ranchers, meat packers, etc. when possible.

ENGAGE:

Help students make connections between past and present learning experiences, expose prior conceptions, and organize thinking towards the essential questions and learning outcomes of the learning sequence.

Learning Target	Using existing knowledge about state geography and reading maps, as well as their existing knowledge of ecosystems, natural resources, and other systems students will analyze the maps and ask questions to construct an explanation about the patterns seen in the maps.
Anchoring Phenomena	Specific soil profiles are better suited for nutritional grazing needs than others.
Essential Questions	• Why does soil impact nutritional needs? • What does soil do? • How does soil work? • What do I know about cattle nutrition? • How can we solve the nutritional needs of cattle with soil information?

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	• What patterns do we see among topography and soil series in Washington and agriculture production? • What are the relationships between the elements the maps show (topography, soil, agriculture)?
Activity	Students view topography maps of Washington. Students will compare soil types, ag production and look for patterns and potential nutritional needs for cattle by area.
Resources	EXAMPLE: Compare maps, look for patterns as well as differences. Look for areas where connections can be made between soil, production and cattle nutrition needs that are needed based upon the topography and soil type. • How do the three maps connect to one another? • WA topography h1.a • WA soil types h1.b • WA agricultural production (look for cattle, wheat, apples) h1.c

EXPLORE:

The purpose is for students to have common, concrete experiences that can be used later when formally introducing and discussing scientific and technological concepts and explanations.

Learning Target	Students experience the interactions among ecosystems, natural resources, and human behaviors. Using scenarios as a context, students evaluate models and obtain information, which leads to asking more questions and investigating patterns, cause and effect, stability and change, and systems.
Anchoring Phenomena	Human or animal activity has an impact on soil and ecosystems.
Essential Questions	• What are the cause-and-effect relationships that we may find in grazing cattle and testing soil quality? • Can people make soil better or worse? • What does “grass/rangeland” mean? • What does “grass/rangeland” look like? • Is there “grass/rangeland” in Washington?

	• What is the soil in a “grass/rangeland” area like? • How do grazing cattle impact soil health in Washington grass/rangelands? • What pattern of ecological interactions are typically found in Washington grass/rangelands? • What do cattle need to survive? • What do I know about nutrient cycles? • How are cattle part of the soil nutrient cycle? • Can cattle be good for soil? • Can cattle be bad for soil? • Can soil be good for cattle? • Can soil be bad for cattle?
Activity	Students interact with available cattle rancher resources around rotational grazing and data-driven carrying capacities as management practices. Students see the result of these actions on the soil and the overall ecosystem. Students may also consider how these practices are similar to the connections made between maps in the **Engage** activity.
Resources	EXAMPLE: Pair students and give each pair a set of the following articles. In the pair, they will decide who will read each article. They will each read an article and share what they learned with their partner, the end goal is to have learned the material of both articles, but only have read one article. • Rotational Grazing Article h2.a • Environmental Impact Article h2.b • Template for collecting thoughts on their article h2.c The end goal is to identify how cattle impact soil, grass/rangeland, and the role this has on nutrient cycles. If time allows, discuss how this connects to the maps they discussed in the **Engage** activity. • How would soil types affect these grazing practices? Additional resources: • Pasture Management: How to grow healthy grass ○ Short video on identifying healthy grass practices • Riparian grazing and healthy water

	◦ A video about livestock grazing and healthy boundaries near water sources. • Stingly Ranches Video ◦ This video shares how this ranch uses multiple grazing practices. • Carbon Cowboy's Video ◦ Mimic herd migration, using art and science and history in grazing practices. • Guardians of the Grasslands ◦ Preserving grassland and the impact of grazing on native prairies.

EXPLAIN:

The purpose is to have the teacher share a model or explanation from the prior engage and explore phase, and have students use resources and information to support learning scientific or technological concepts.

Learning Target	Critically review scientific information about natural resources, cycles and systems, biodiversity, relationships in ecosystems, how ecosystems function, and human impacts to ecosystems, including concepts like systems, matter, function, stability, change, cause-and-effect, and patterns.
Anchoring Phenomena	There are many beneficial interactions between cattle and soil.
Essential Questions	• What does soil do? • What are the soil characteristics of grassland biomes in Washington? • Are there living things in the soil? • What are living things in soil? • What does soil look like under a microscope? • What are ecological interactions? • What are examples of ecological interactions I am familiar with? • Do "grass/rangelands "matter to me? • What is the impact on the climate?

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Activity	**Suitable soil:** ● Students learn key soil vocabulary, inspect different types of soil and investigate their components. Students compare soil characteristics for its health. **Grass/rangeland Ecosystems:** ● Students are given the components of the grassland ecosystem and explanations of each component. Then create a lego model. **Ecosystem Patterns:** ● Students will create a food web including cattle and grass/rangelands.
Resources	EXAMPLE: Here are resources to explore further the learning around Suitable Soil, Grass/rangeland Ecosystems, and Ecosystem Patterns. ● Suitable Soil h3.a ● Grassland Ecosystems h3.b ○ Students will use legos to create an ideal grass/rangeland ecosystem. ● Ecosystem Patterns h3.c ○ Students will create a food web after reading about ecosystem patterns.

ELABORATE:

The purpose is to involve students in further experiences that apply, extend, or elaborate the concepts, processes, or skills they are learning.

Learning Target	Students will analyze and interpret data and information regarding specific ecosystems, and, using evidence, predict the likely outcomes, whether stability or change in cause and effect relationships.

Anchoring Phenomena	Cattle are better suited to graze on specific soil types in Washington than others.
Essential Questions	• What does it mean for soil to be suitable for growing different things? • How do management decisions impact soil health? • What do you think would happen if?
Activity	Students are given existing soil series in Washington and asked to predict the likely outcomes of cattle grazing.
Resources	EXAMPLE: Each student will be given a type of soil in Washington. The students will predict the likely outcomes of grazing based upon their previous knowledge gained in the Engage, Explore, and Explain phase activities. Examples: • Freeman Series Soil h4.a • Pogue Series Soil h4.b • Nevine Series Soil h4.c • Quincy Series Soil h4.d • Scoon Series Soil h4.e • Seattle Series Soil h4.f • Springdale Series Soil h4.g • Varodale Series Soil h4.h • Wahluke Series Soil h4.i

EVALUATE:

The purpose is to use feedback from the previous 5E steps either formally or informally.

Learning Target	Students will construct explanations of relationships among ecosystems, natural resources, and other systems using models.
Anchoring Phenomena	Students develop scientifically based explanations for the phenomena.
Essential Questions	• How do grass, rangelands impact soil? • How do cattle impact grass, rangelands?

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	● How does soil impact cattle and grass, rangelands? ● How do humans play a role?
Activity	Students develop a comprehensive, scientifically based explanation of the relationships among humans, cattle, soil, nutrition and grass/rangeland ecosystems. Students may use a variety of modalities to document and share their descriptions and explanations. Their evidence could come from what they learned in the **Engage**, **Explore**, **Explain**, and **Elaborate** phases.
Resources	EXAMPLE: Students will answer questions showing scientific evidence. They can answer questions with models, written explanations, videos, etc. They should back up their answers with data and information learned through the 5E learning model. They could use a visual presentation such as Prezi, or Google slides. Or they could make a poster or write their answers on paper. The evidence should be able to be given in a variety of ways. Example: ● Evaluation h5.a

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