4

SOIL

MODULE 4 | Investigating Rangeland Systems and Practices

SKILL LEVEL

Middle School: Grades 6, 7, 8

KEY TERMS

Soil, organic matter, sand, silt, clay, parent material, climate, weathering, arthropod, bacteria, soil food web

EDUCATION STANDARDS

SD Science:

- MS-LS2-3

NGSS:

- MS-LS2-3

TIME NEEDED

Activity 1: 40 min
Activity 2: 50 min
Activity 3: 50 min
Activity 4: 10-15 min

MATERIAL LIST

- Chalkboard or whiteboard
- Print items in Appendices
- Computer w/ projector
- Materials listed for each activity

ACKNOWLEDGEMENTS

This material is based upon work that is supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, under agreement number 2019-38640-29879 through the North Central Region SARE program under project number LNC19-419. USDA is an equal opportunity employer and service provider. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.

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EXPECTED LEARNER OUTCOMES

OBJECTIVE 1
Students will learn about factors that influence soil formation.

OBJECTIVE 2
Students will learn what soils are composed of and how soil types can differ based upon area and land characteristics.

OBJECTIVE 3
Students will learn about rangeland soil ecology and the animal-interaction component, as it relates to the cycling of matter and the flow of energy.

Funding provided by USDA North Central OSARE Award #2019-38640-29879

OBJECTIVE 4

Students will learn that less disturbed soils have more "soil glue" compared to more disturbed soils, demonstrating why it is important to protect soils from disturbance.

Figure 1. The importance of soil.

BACKGROUND

Soil provides us with lots of benefits and helps to support land-based animal and plant life and is a critical component of rangeland systems. It makes up the outermost layer of Earth and is where plants and trees grow. Soil can sometimes be called other things such as "earth" ('Earth' with a capital 'E' refers to our planet; 'earth' with a small 'e' refers to soil) or "dirt." Dirt is simply displaced or loose soil. Soil is made up of air, water, inorganic mineral particles, and organic matter (25%, 25%, 45%, and 5%, respectively).

The inorganic materials in soil are the non-living parts of the soil – these parts will be referred to as sand, silt, and clay. The inorganic materials are highly important for building soil texture. In contrast, the living parts of the soil are the organic materials, and are known as "**soil organic matter**, or SOM." SOM has a lot of nutrients in it that are important for plant growth and the overall health of soil, plants, crops, animals, insects, and other beneficial bugs.

Several factors influence how soil is created, which is a process that can take 100s to 1000s of years. There are five main factors that influence soil formation: climate, organisms (vegetation/biology), topography (land features), weathering of parent material, and time.

Climate helps explain why soils are not the same across the world. Different temperatures and moisture levels influence the amount and speed of weathering. As an example, rocks break down more quickly in a warm, wet climate compared to a cold, dry climate because reactions happen quicker. The type of precipitation (rain, hail, snow) that occurs in each area, as well as the amount, force, and timing of it also influence weathering rates. Climate also influences the number and types of plants and animals in an area, and how fast or slowly they decompose after they die, ultimately producing soil organic matter.

Organisms, like plants and animals (that students learned about in Modules 2 and 3, respectively), play a role in soil formation. Bedrock, i.e. **parent material**, is first broken down by *physical* weathering (described below), and then is broken down even further by *biological* weathering. Animals and microbes (bacteria and fungi) help mix soils as they move around, making tunnels and small spaces in between soil particles. Eventually, plants and animals die and become part of the soil organic matter as they decompose after dying. We as humans also count as organisms and impact soil formation. Constructing buildings, cutting down forests, and agriculture also influence soil formation by changing how quickly soil is formed or worn away.

Topography, or land features, are the physical features of where you are on a given landscape. Topography has a large role in soil formation. A hill slope or a mountain can affect the moisture and temperature of the soil. Soil is easily washed or blown away on steep slopes. As a result, the soil on a mountain or hillside is often thinner compared to the soil down in a valley – the soil on the hillside erodes more quickly and goes downhill and collects in the flatter areas.

Weathering of parent material (physical weathering) occurs from just that – the weather. The frost, wind, snow, rain, sunshine, etc. all act as forces on rocks – this is called "weathering." Weathering occurs over 100s of years, and breaks the bedrock of the Earth into small particles that make up the inorganic materials of soil (e.g. **sand**, **silt**, **clay**).

Time is the last factor that influences soil formation. Soil formation takes place over 100s or 1000s of years and can take that long to form even 1 centimeter of soil!! Unfortunately, that 1 centimeter of soil can be washed away in hours or days if the soil is not protected (i.e. it does not have a living root in it to help absorb any precipitation received). Over time, soils develop an internal structure and what are known as soil horizons are formed. Different soil horizons have different properties, which students will learn about in Activity #1.

Each state has its own state soil. In South Dakota, the state soil is Houdek. Students will read and learn about Houdek soils and why they are important from an agricultural perspective. Next, students will draw their own soil profile to help remember the characteristics of each soil horizon.

A large piece of soil formation comes from organisms. In fact, the diversity that exists within soil is greater than the diversity that is found above ground, when it comes to organisms. ***Specifically, there are more living organism in 1 tablespoon of soil than there are people on Earth (about 7 BILLION people).*** There are many different types of organism that live in the soil, including arthropods, bacteria, fungi, worms, and small animals like moles and mice.

Arthropods are animals that don't have backbones; instead, they have their skeleton outside their body. Arthropods assist bacteria in the soil, by shredding dead plant material into smaller portions for the bacteria to digest. In addition, arthropods spread nutrients, add minerals to the soil through their waste, and burrow through the soil which helps to create avenues for oxygen to move through.

Bacteria were some of the earliest forms of life on earth and are found everywhere. Bacteria help plant roots gain nutrients from the soil. In fact, bacteria are extremely important in the process of nitrogen fixing – they help take nitrogen in its gas form and turn it into usable compounds that plants can use. Other types of bacteria take nitrogen from decaying matter in the soil and transform it into a usable form for plants.

Fungi include mushrooms, but also a whole host of an underground network that can span for miles. Fungi have an important role in soil health and soil formation – they decompose organic material into forms that

other organisms can use. Fungi can help increase water absorption and the ability of a soil to hold water because they help to hold soil particles together. Fungi make proteins such as glomalin, which oozes into the soil and acts as "soil glue," helping the soil particles stay together. When soil particles are glued together into **soil aggregates** (clumps of soil particles that are held together by clay, fine roots, and microbial residues like glomalin), then the pores and channels in soil are better maintained, allowing air and water to enter and move through the soil much easier. Soil aggregates are better able to withstand rainstorms, i.e. the soil does not wash away because it is held together.

Worms like earthworms are often thought of as "soil engineers" because of how useful they are to soil!! If you find earthworms in soil, it is usually a sign of healthy soil!! The tunnels that earthworms create as they move through soil helps air circulate and oxygen can more easily reach plant roots and other organisms in the soil. Earthworms also bring nutrients into the soil, by eating the soil and breaking it down into organic matter. Worm poop or "worm castings" is a way that worms release nutrients into the soil, in a form that can then be used by plants. One fun fact is that earthworms have one brain, five hearts, and it breathes through its skin!!

Arthropods, bacteria, fungi, worms, and small animals all work together for the cycling of matter and flow of energy among the living and nonliving parts of an ecosystem to create a soil food web. Students learned about photosynthesis in Module 2: Plants and will take those concepts and use them to create a soil food web.

VOCABULARY

SOIL: the upper layer of earth in which plants grow

SOIL ORGANIC MATTER: the organic matter component of soil, consisting of plant and animal detritus at various stages of decomposition

SAND: a loose granular substance; a component of soil

SILT: very fine sand, clay, or other material; a component of soil

CLAY: stiff, sticky fine-grained earth, typically yellow, red, or bluish-gray in color; can be molded when wet; a component of soil

LOAM: a soil with roughly equal proportions of sand, silt, and clay

PARENT MATERIAL: bedrock found in the Earth; it is weathered and eroded (broken down) into smaller and smaller particles that make up the inorganic material of soils, like sand, silt, and clay

CLIMATE: the average or typical weather conditions for a specific area

WEATHERING: the breaking down of rocks, soils, and minerals

ARTHROPODS: animals that do not have a backbone and instead their skeleton exists outside their body

BACTERIA: microscopic living organism that are usually one-celled, that are found everywhere

FUNGI: living organisms that are not animals, plants, or bacteria, and unlike bacteria, have complex cells. Fungi reproduce via spores. Examples include yeasts, molds, and mushrooms.

SOIL AGGREGATES: clumps of soil particles that are held together by clay, fine roots, and microbial residues like glomalin, a protein made by fungi

SOIL FOOD WEB: the community of organisms that live all or part of their lives in the soil. The conversion and exchange of energy and nutrients occurs throughout the soil food web when one organism eats another.

PRIMARY PRODUCER: organism that get their energy from the sun, eg) plants.

DECOMPOSER: an organism that breaks down (decomposes) organic matter, eg) bacteria and fungi.

PREDATOR: an organism that eats (preys) on other organisms, eg) arthropods or a mole.

ACTIVITY #1: SOIL FORMATION FACTORS AND SOIL PROFILES

ESTIMATED TIME: 40 MIN

Materials

- PowerPoint PDF "How do soils form? CLORPT for short" (on the jump drive) (1 copy per group)
- PowerPoint Presentation "Soil formation – profiles" (on the jump drive)
- Flip chart paper (1 per group)
- Markers (1 set per group)
- Handouts #1 – Soil Formation Factors (1 per student)

1. Get students together in groups of 4-5 students. Hand each group a copy of the PowerPoint PDF "How do soils form? CLORPT for short."
    a. Ideally, there will be 5 groups.
2. Assign each group one of the five factors of soil formation:
    a. Climate
    b. Organisms
    c. Relief
    d. Parent Material
    e. Time
3. Ask each group to write down their factor on the flip chart paper and review the corresponding pages in the PowerPoint PDF.
4. Next, have students use either words or drawings on the flip chart paper to communicate what their soil formation factor is.
5. Allow each group to come to the front of the classroom and explain what soil formation factor they were assigned. This allows students to teach one another about a concept they have learned, helping to enhance their learning.
6. Once students are back at their desks with their group members, provide each student with Handout #1, which has questions about soil formation that will set the foundation for the following activities in this Module.
7. Have students work through Handout #1 with their group members, and then go over the answers as a group, asking students to speak up and share their thoughts.
    i. Question 1: What has helped you, as a person, develop over time?
        1. Possible answers: where you live (i.e. the climate), what you eat (i.e. organisms), where on the landscape you live (i.e. relief/topography), parents (i.e. parent material), how old you are (i.e. time). Guide students to these answers.
    ii. Question 2: What is the difference between "weather" and "climate"?
        1. Answer: Weather = is tied to a specific place and occurs over a short period of time. An example is that one day could be sunny, and one day could be overcast. Climate = the average weather conditions for an area. Climate occurs over a longer period.
        2. Answer: Climate dictates what clothes you need in general for where you live. If you look out a window, you check the weather, and can decide if you need to wear a rain jacket or shorts for the day.
    iii. Question 3: What are some organisms that are present in the soil that help soil form?

1. Answer: voles, moles, mice, bacteria, fungi, plant roots – all of these are present in the soil and as they move around and make tunnels (for voles, moles, and mice) or create spaces (for roots), then water can enter the soil and the weathering process can continue.

iv. Question 4: Make sure students understand that location on the landscape has a large role in soil formation. Where would a deep soil be located on a hill – at the top or at the bottom?
    1. Answer: A deeper soil is on the bottom of a hill, called a "toeslope," as soil moves down the hill and collects at the bottom, creating a deeper soil. This contrasts with less developed soils at the top of the hill.

v. Question 5: What do you think is meant by the words "parent material"? What does it mean to have a parent?
    1. Answer: Like each individual has characteristics from their parents – you might get your mom's eye color, or your dad's hair color – the same is true for soils. Parent material is the material that soil develops from. This material can come from transported sediments, bedrock, or organic materials.

vi. Question 6: How does nature move material?
    1. Answer: Water, wind, gravity, and ice!

vii. Question 7: How are we different from people who are older than us?
    1. Answer: They have had more experiences in life and have had longer to develop – just like soil! Soils that are older are more developed because they have experienced more weathering.

8. Next, review the PowerPoint Presentation "Soil formation – profiles" with students.
    a. Ask students the following questions as you go through the PowerPoint:
        i. Slide 3: How is a soil profile different from a soil horizon?
            1. Answer: A soil profile is a vertical view of the soil and is composed of many soil horizons. A single soil horizon is a layer of soil that is parallel to the ground/horizontal.
        ii. Slide 4: Go through each soil horizon with students, keeping in mind that the following slides will have greater detail. Will all soils around the world have each one of these soil horizons?
            1. Answer: No – each soil will be different because the CLORPT factors that influence soil formation will be different depending on where in the world you are located.
9. Assign students to break into groups of three.
    a. Have students create a mnemonic device on their own to remember the soil horizon order (O, A, E, B, C, R).
        i. Some examples of mnemonic devices:
            1. ROYGBIV = Red, Orange, Yellow, Green, Blue, Indigo, Violet
            2. CLORPT = Club Organizes Running Parent Times for CLimate, Organisms, Relief, Parent material, Time as the factors that influence soil formation
            3. OAEBCR = Our Aunt Ethel Bakes Cookies Regularly for the O, A, E, B, C, R soil horizons
    b. Allow each group to present their pneumonic device to the class.

ACTIVITY #2: SOUTH DAKOTA SOILS

ESTIMATED TIME: 50 MIN

Materials

- "South Dakota State Soil – Houdek – Limited" handout (1 per student, on the jump drive)
- Handout #2 – Houdek Questions (1 per student, in the Appendix)
- Handout #3 – Houdek Soil Profile (1 per student, in the Appendix)
- Coloring pencils or markers (hand out per group of students to share)

1. Each state chooses a specific state soil that has significance. The South Dakota state soil is Houdek. Hand each student a Houdek handout, get them into groups of 4, and have them take turns reading through the different sections of the Houdek handout.
2. Give each student Handout #2 – Houdek Questions, which has questions that each student can answer as they read through the handout.
    a. Question 1: What are some characteristics of Houdek soils?
        i. Answer: (Page 2 of the handout) Houdek soils have a topsoil (A horizon) that comes from the weathering of glaciers. The subsoil in a Houdek (B horizons) accumulate clay particles and lime.
    b. Question 2: What was your pneumonic device for how to remember the factors that influence soil formation? How have these factors specifically influenced Houdek soils?
        i. Answer: (Page 2) CL-O-R-P-T, Climate, Organisms, Relief/Topography, Parent Material, Time.
        ii. Climate – Houdek soils developed in a sub-humid climate with quite a bit of rainfall (20-22 inches per year) and a mild temperature (45-47°F).
        iii. Organisms – Houdek soils were developed and formed with the influence of plants and animal life. Plants are important in forming Houdek soils because Houdek soils have mid-grass prairie vegetation, which deposits organic matter through plant root additions and decompositions.
        iv. Relief/Topography – Houdek soils are very deep and are well-drained, and are found in more upland areas (i.e. not in "bottoms," or areas that are lower in elevation). Houdek soils are also not very steep, with slopes ranging from 0-6%.
        v. Parent Material – Houdek soils developed from glacial till, which is simply what is deposited by a glacier.
        vi. Time – In general, less time is needed for a soil to develop in a humid and warm area with lots of vegetation/plants – this is where a Houdek soil is found, compared to an area that is cold and dry with little vegetation.
    c. Question 3: Why are Houdek soils important in South Dakota?
        i. Answer: (Page 3) Soil is extremely important for agriculture, ranking in the top 10 for corn, soybeans, wheat, and many other crops. In addition, soil is also very important for forage, rangeland, and pasture that exists throughout the state, providing feed for livestock like cattle. South Dakota typically ranks in the top 10 for beef, sheep, hog, bison, and honey production!
            1. Without productive soils, we wouldn't be able to produce all the agricultural products in South Dakota that we do!!
            2. Note that large areas of Houdek soils are considered native rangeland.

3. Hand each student Handout #3 – Houdek Soil Profile and give each group of students the coloring pencils or markers.
    a. Ask each student to draw the soil profile of a Houdek soil, referring to Figure 2 in the Houdek handout.
    b. Note: Students can ignore the sub-classification of the horizons (i.e. "Ap" for the A horizon, and instead just label it "A horizon." Likewise, the "Bt" and "Bk" horizons can be grouped together for this exercise into one bigger "B horizon".)
    c. Once students have some time to draw the soil profile and label each horizon, have them write 1-2 characteristics of each horizon next to their soil profile drawing.
    d. Go through Handout #3 – Houdek Soil Profile with the students, asking students to participate and share their drawing with the class. The horizons and corresponding characteristics that a Houdek soil has are:
        i. A horizon – topsoil, it has a mix of organic matter and mineral material, dark in color
        ii. B horizon – subsoil, the "zone of accumulation" in the soil. The zone of accumulation is where any chemicals that are present in the upper soil horizons will "leach" or travel down to the B horizon.
        iii. C horizon – parent material, this represents what the glacier originally left behind.

ACTIVITY #3: SOIL GLUE AND SOIL FOOD WEB

ESTIMATED TIME: 50 MIN

Materials for Demonstration – Soil Glue

- 2 wide mouth glass jars
- 2 pieces of ¼ inch wire mesh – about 1.5 x 6 inches
- 2 clods of soil, about the size of an egg each
    - Take samples from two different areas (e.g. a lawn, a construction site, a farmer's field that has been plowed (disturbed), a well-managed rangeland, a forest, a worn down path).
    - Take each sample from the top 2 inches of soil.
- Masking tape to label each jar
- Handout #4 – Soil Glue Demonstration (1 per student)

Materials – Soil Food Web

- Handout #4 – Soil Food Web (1 per student)
- Coloring pencils or markers (hand out per group of students to share)

Demonstration – Soil Glue

1. One main part of soil formation is Organisms, (CLORPT), which are part of the soil food web. The soil food web is a community of organisms that live all or part of their lives in the soil. As outlined in the Background section of this module, fungi in the soil produce a protein called glomalin, which acts as soil glue. Depending on where soil is from and how it has or has not been managed, can influence how well and how long a soil stays "glued together." This demonstration will get students thinking about the microorganisms (fungi and bacteria) that are present in the soil, and will be the jumping off point for students developing their own soil food web.
2. Provide each student with Handout #4 and tell them where each soil sample has been taken from.
3. Ask one student to fill each jar with water to within 0.5 inches of the top.
4. Ask another student to shape each piece of wire mesh so that it sits about 1.5 inches below the top of each jar.
5. Next, label each jar with the masking tape, writing down where each soil sample has been taken from – make sure that the writing is large enough for most of the students to see, as they will be writing down their observations during the demonstration.
6. Place each piece of soil onto the wire rack.
7. Ensure that students have Handout #4 in front of them to record their observations.
8. Lower each soil sample on the wire rack gently into the jars.
9. Discuss the observations with the class – go through the questions with them on Handout #3.

Activity – Soil Food Web

1. Ask students about the following terms and write their answers on the board or a large sticky note.
    a. **Primary producer:** an organism that makes its own food.
        i. Examples of primary producers are plants, which students learned about in Module 2. Plants use the process of *photosynthesis* to turn carbon dioxide and sunlight into food that provides them with energy. Other examples of primary producers include moss, lichens, and algae.
    b. **Decomposer**: an organism that breaks down (decomposes) organic matter.

i. Examples of decomposers include bacteria and fungi. They help break down nutrients in the soil such as nitrogen, phosphorus, and calcium to name a few. These decomposed nutrients are then taken up by plants, the primary producers.

c. **Predator:** an organism that eats (preys) on other organisms.
   i. Examples of predators in the soil include arthropods and moles. They not only eat other organism, but as they move through the soil they create tunnels and help move the soil around, allowing oxygen to reach the soil to help break it down.

2. Next, provide students with Handout #5 and have them fill in the table with the definition and an example.
3. Give small groups of students coloring pencils and markers and have them flip over Handout #5 and create their own soil food web.
   a. This will be a great activity to have students incorporate what they already have learned in Modules 1, 2, and 3. For example:
      i. Where is their food web located? Can they draw a soil food web in a rangeland?
      ii. What larger animals exist in the ecosystem?
         1. Answer: Some examples are sage grouse, hawks, antelope, bison, horses, coyotes, cows.
      iii. What do those animals do?
         1. Answer: They eat and pee/poop out important nutrients for the systems.
      iv. What happens to the piles of poop in a rangeland? Do they sit on top of the ground forever?
         1. Answer: No! Decomposers such as dung beetles start to eat and move around the poop and bring it into the soil profile where it is decomposed even further by bacteria and fungi.
      v. What process do plants use to create their own food?
         1. Answer: Photosynthesis – they capture carbon dioxide and sunlight and form it into a usable sugar they can use for energy and growth.
      vi. What animals graze the grasses and forbs? What happens to the grass as it is grazed?
         1. Answer: Herbivores such as cattle and horses graze the plants. When the grass is grazed, the animals remove the older, less effective leaves, which helps the plant produce more, nutrient-rich, young leaves that animals really enjoy eating. Grazing also stimulates root growth and helps the roots grow more densely.
4. As a conclusion, allow each student to come up to the board and add one piece of the soil food web. Once the entire class has come up to the board, review what the class developed for the soil food web.

ACTIVITY #4: CLASSROOM ASSESSMENT

ESTIMATED TIME: 10-15 MIN

3-2-1 Format for Activities #1 and 2

1. Have each student get out a piece of paper.
2. Ask students to write down:
   a. 3 ideas that were presented
   b. 2 examples of how they can use their knowledge of soils
   c. 1 unresolved area/"muddiest" point that they didn't quite understand
3. Have students get into pairs and share their 3-2-1 with a partner.
4. Ask students to turn in their paper; read through them to gauge how well students understand Activities #1 and 2, paying particular attention to the 1 unresolved area/"muddiest" point to go over with the class again to clarify their learning.

ESTIMATED TIME: 10 MIN

Focused Listing for Activity #3

1. Focused listing allows an instructor to determine what students can recall from a lesson.
2. Select an important topic or concept that was covered in Activity #3. For example, you might pick "soil glue" or "soil food web." Place this phrase on the board.
3. Set a timer for 5 minutes and ask students to list important words and phrases about the topic you selected.
4. Review the findings with the class, filling in any key concepts that students missed, as a way to review the activity.

SOIL FORMATION FACTORS

Name: _____

1. What has helped you, as a person, develop over time?

2. What is the difference between "weather" and "climate"?

3. What are some organisms that are present in the soil that help soil form?

4. Where would a deep soil be located on a hill – at the top or at the bottom?

5. What do you think is meant by the words "parent material"? What does it mean to have a parent?

6. How does nature move material?

7. How are we different from people who are older than us?

HOUDEK QUESTIONS

Student name: _____

As you read through the "South Dakota State Soil – Houdek – Limited" handout, think about the importance of agriculture and what you have learned so far about soils, as you answer the following questions.

1. What are some characteristics of Houdek soils?

2. What was your pneumonic device for how to remember the factors that influence soil formation? How have these factors specifically influenced Houdek soils?

3. Why are Houdek soils important in South Dakota?

HOUDEK SOIL PROFILE

Student name: _____

Instructions: Draw the soil profile for the state soil of South Dakota, a Houdek soil. Be sure to include the soil horizons that are found in a Houdek and include a characteristic or two of each horizon.

Funding provided by USDA North Central OSARE Award #2019-38640-29879

SOIL GLUE DEMONSTRATION

Student name: _____

1. What is the source of each soil sample? Where is it from? Record it in the table below.

Soil 1	Soil 2

2. Once your teacher lowers the soil sample into the water, watch the results and record your observations in the table below.

Soil 1	Soil 2

3. Did both samples react the same way? Did the soil stay together or fall apart?

4. Was the water clearer in one jar compared to the other jar?

5. If the water became cloudy, did it clear up again? How long did it take to clear?

6. Which soil would have more pores in it after a rain storm?

7. Which soil is more likely to resist erosion during a rain storm – which soil held together better?

SOIL FOOD WEB

Student name: _____

1. Fill out the table below with definitions and examples of primary producers, decomposers, and predators that you would find in the soil.

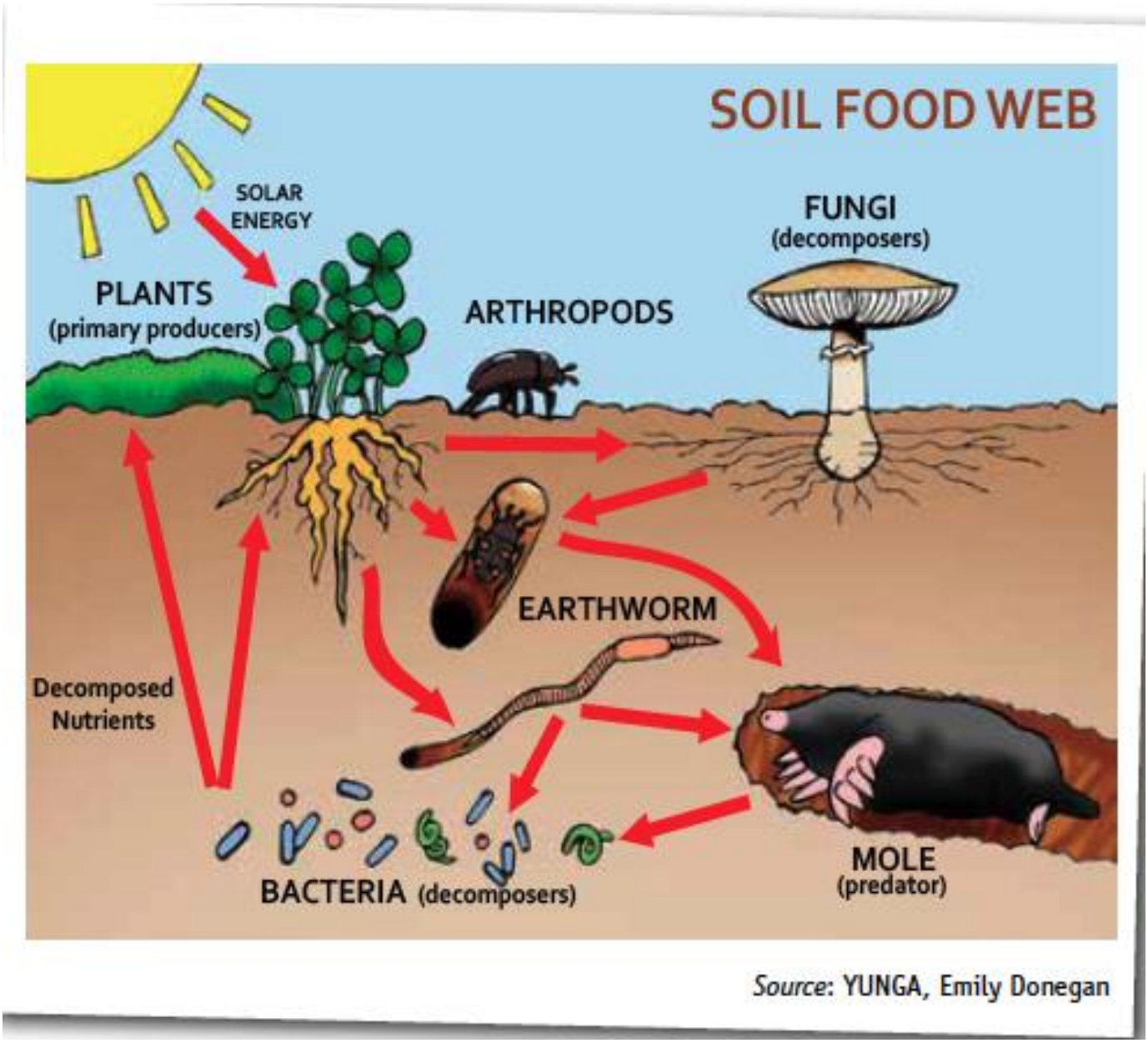
Primary producer	Decomposer	Predator
Definition: Example:	Definition: Example:	Definition: Example:

(Flip over.)

2. Instructions: Draw a soil profile with at least three different soil horizons – you can draw a Houdek soil if you want. Make sure you place this near the bottom of the page. Next, draw in the organisms that are part of the soil food web. Be sure to label each organism as a primary producer, decomposer, or as a predator.

APPENDIX: RESOURCES

EXAMPLE OF A SOIL FOOD WEB



(Source: FAO 2015)

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