United States Department of Agriculture

Soil Science Curriculum

Content and lab derived from the USDA-NRCS Guides for Educators. Go to https://www.sdsoilhealthcoalition.org/soil-health-buckets/ for the Guides and additional pictures and diagrams.

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Soil Aggregates: Role in soil health and measuring stability

Approximately 60 minutes

Objectives

By the end of the lesson, students will know or be able to:

- Define soil aggregate, mycorrhizal fungi, hyphae, plant root exudates, glycoprotein
- Explain why a soil aggregate is important to soil health
- Demonstrate and/or measure soil aggregate stability
- Describe management practices that sustain or improve aggregate stability

Preparatory Work

- Print all necessary copies
- Secure permission to collect soil from the landowner(s)
- Collect surface soil from a well-managed cropland field that is not tilled, and from one that is conventionally tilled, about 2 cups of each
- Set up a table with a disposable tablecloth or paper
- Provide sheet with definitions

Materials

- 3-inch foam balls
- 1-inch or smaller foam balls
- Post-it notes or 3x5 index cards
- Slender wooden dowels, toothpicks and/or coffee stirrers
- String licorice (different colors)
- Silly string
- Roll of monofilament string (fishing line)
- Small plastic animals (farm animal set & jungle animal set - optional)
- Baby or foot powder
- Sink strainers (at least 2)
- Disposable cereal bowls
- Water (about a quart)
- Flat plastic lid or cutting board

Enroll the Participants *(Approximately 30 minutes)*

Hand out about 10-15, 3-4-inch-long dowels/toothpicks/stirrers, one set per student; about four to five 3-inch foam balls, about seven to none of the smaller foam balls, and two to thee index cards/Post-it notes roughly torn into four pieces. Have a student with a dowel insert it into the foam ball from another student, and place on the tablecloth. Have a student with an index card piece place it on the dowel (you may have to pierce the paper with a small hole to get it started on the dowel). Add another foam ball to the other end of the dowel and insert another dowel to one of the foam balls that is already attached to the other dowel. It may help to have glue on hand and apply to the ends of the sticks as you build the aggregate. The object is to build a soil aggregate "lattice", something like what is shown in Figure 1.

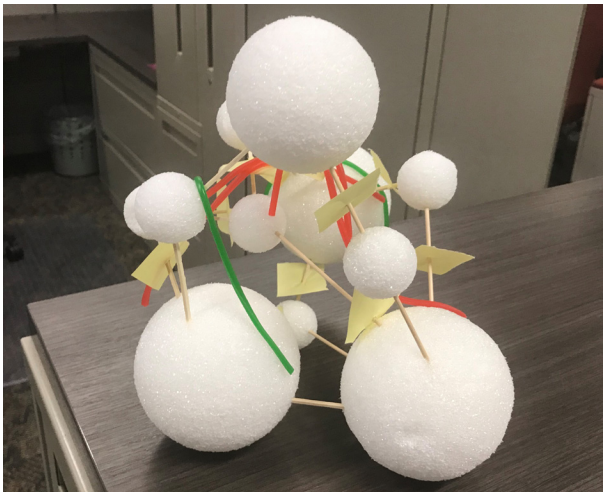

Figure 1

As you are building the soil aggregate, explain that the large foam balls represent sand particles, the smaller foam balls represent silt particles, and the Post-it note/index card pieces represent clay particles. The dowels represent weak bonds between the soil particles that would normally break very easily when the soil gets wet.

Next, hand out a few of two colors of the string licorice, and have the students lay them on/in the lattice. Explain that one color represents mycorrhizal fungi, and the other color represents plant roots.

Then give a can of the silly string to a student (or two cans, one to each of two students), and have them spray some silly string on the soil aggregate. silly string represents glycoproteins that help glue the soil aggregate together.

(Optional) Take some of the farm animals and jungle animals, and have the students place them on/in the soil aggregate. You can ask an additional question about what the animals represent. They represent soil microbes that make the aggregate their home (habitat). Some soil microbes are predators, like the lion or tiger, and some are prey, like the sheep. You can use paper cut-out animals if you don't have the plastics ones available.

Take one end of the monofilament string and tie it off to a "plant root" or just attach it to the soil aggregate, then roll the string out across the floor. This represents mycorrhizal fungi hypae, which are basically like the roots of the fungi. They connect to the plant roots and greatly increase the area of the soil from which the plant roots can get water and nutrients. You can initially wrap the string around your arm and explain that the hyphae are like an IV that you get when you go into surgery, and acts the same way, supplying fluids and nutrients/medicines between the plants and fungi.

You can also attach a dollar bill to one of the foam balls, and when you destroy the aggregate (below), you can see the money (fertilizer, organic matter, etc.) eroding away.

Use the following questions to facilitate a conversation with the students:

What does the silly string represent? Answer: Plant roots give off exudates, which are basically sugars – sugar is sticky, and these act like glues that help hold the aggregate together. Mycorrhizal fungi give off glomalin, which is another "glue" that helps hold the aggregate together. Earthworms are slimy, and this slime is another glue – all these glues make the soil aggregate very strong and stable.

What do you think would happen to the aggregate if the soil is disturbed (tilled)? Answer: After you get some answers from the students, you can demonstrate what will happen by smashing the soil aggregate with your hand, and say this is a disc or plow.

What will happen to the individual soil particles with disturbance/tillage?
Answer: Erosion – you can demonstrate by taking one of the foam balls and rolling it across the floor, and say "this is like wind or water erosion". Also, the first thing to leave during an erosion event is light organic matter particles in the air or water. You can demonstrate this with the baby/foot powder, by squeezing the bottle up into the air – it is like the carbon dioxide leaving with disturbance but you can't see carbon dioxide.

What happens to the mycorrhizal fungi and their hyphae with disturbance/tillage? Answer: You can demonstrate the answer by showing that the hyphae are disconnected now from the plant root, and you can pull out a licorice string and break it into pieces.

There are other analogies you can draw from this demonstration, use your imagination.

Provide the Experience *(Approximately 3 minutes)*

Review the laboratory scenario with students.

A local farmer has been farming with a rotation of corn, soybeans, wheat, and sunflowers, and has been practicing no-till for 14 years. As often as possible, cover crops are incorporated into the rotation. The farmer recently decided to rent some adjacent land but found that the field cannot be entered into as early as the land currently being farmed. Water is often ponding in the rented field after a rain, and erosion is happening, even forming small gullies in some places.

Label the Information *(Approximately 3 minutes)*

Review and identify each of the supplies that will be used during the lab activity.

- Sink strainers
- Disposable cereal bowls
- Water
- Two soil samples, one from no-till and one from conventional till

Demonstrate the Relevance *(Approximately 25 minutes)*

Steps:

1. Fill one sink strainer level to the top with soil from the no-till field. As you are filling the sink strainer, gently break apart the soil into the naturally occurring aggregates. Do not overly work the soil sample into fine particles or crush the aggregates.
2. Repeat step 1 with the conventional tilled soil into the other sink strainer.
3. Fill the disposable cereal bowls with water to the brim.
4. Place each soil sample in the sink strainers gently into the bowls with the water. Ensure that the entire soil sample is in full contact with the water. Let the samples soak for approximately 30-60 seconds.
5. Remove each soil sample from the bowls and turn the sample over onto the flat plastic lid or plastic cutting board so that the entire sample remains on the lid/board. Place the samples several inches apart.
6. Raise one side of the board/lid slightly so the water starts to move away from the samples and observe the differences.

This is one method to test for soil aggregate stability and is also known as the slump test. The sample with good aggregate stability will “stand up” higher and the individual soil aggregates will still be visible. The sample with poor aggregate stability will ooze down the board/lid and will be “soupy”. One analogy that works is the good aggregate stability sample will look like a chocolate brownie, and the poor aggregate stability sample will look like chocolate pudding. Often times the good sample will be darker than the poorer sample, and they will often smell different (the good sample will have an earthy smell, or the smell after a rain, while the smell of the poorer sample will be variable). Figure 2 shows an example of the results of this test.

Figure 2

Definition

Glycoprotein: a sticky substance produced abundantly by hyphae and spores of mycorrhizal fungi in soils – it is an exudate of the fungi; acts as a glue holding soil particles together into aggregates.

Hyphae: long, branching filamentous structures of the mycorrhizal fungi that transport water and nutrients from the soil to the main fruiting body of the fungi and to the plant roots with which they are associated – similar to the roots of a plant.

Mycorrhizal fungi: these are fungi that form a symbiotic relationship with plants, and attach to or into the plant root and provide water and nutrients to the plant – the plant in turn supplies food to the fungi; these associations greatly increase the extension of the roots in to the soil profile area in the soil which is available to the plant.

Plant root exudates: these are polysaccharides or basically sugars produced by plant roots that are used by many soil organisms for food, and help build soil aggregates.

Soil aggregate: soil particles held together by organic matter and related substances. Well aggregated soils have higher infiltration rates and are less prone to erosion. Aggregates also provide habitat for soil microorganisms.