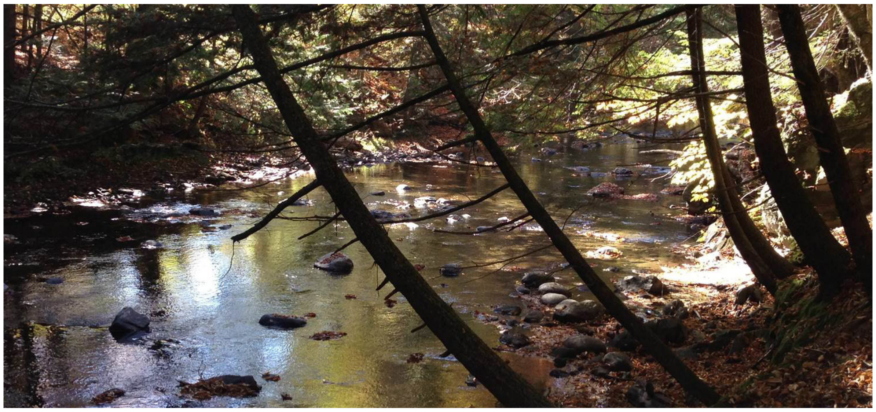
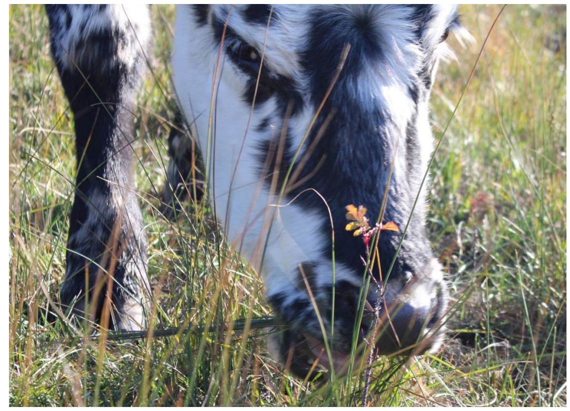
UNDERSTANDING *Soil Health* and *Watershed Function*

A Teacher's Manual



DIDI PERSHOUSE

A joint project of: The USDA Natural Resources Conservation Service, The USDA Southern Plains Climate Hub, The Soil Carbon Coalition, Redlands Community College, The Dixon Water Foundation

September 29, 2017 Reviewer's Edition

USDA United States Department of Agriculture
Southern Plains Climate Hub

USDA United States Department of Agriculture
Natural Resources Conservation Service

DixonWaterFoundation

REDLANDS COMMUNITY COLLEGE

soil Carbon coalition

UNDERSTANDING
Soil Health and *Watershed Function*

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The Story of This Manual

Since 2007, I have been writing about parallels between medicine and agriculture, looking at them as two forms of care for complex systems. The emerging understanding of the importance of microbial communities as the basis of human health and soil health has been fundamental to my understanding of both systems.

In 2011, a storm swept through the rural area where I live. It swelled the rivers and streams and tore up 500 miles of roads and 250 bridges. Entire farm fields ended up downriver and sewage overflowed into gardens and ponds. Everywhere I drove, I stopped to look at the way a few inches of heavy rain had cut through hillsides, moved rocks, trees, even houses. Many people lost jobs after businesses flooded. Over the next few months, I watched as workers rebuilt roads, and piled up rocks along river banks, and I wondered: Are they treating the root cause or just the symptoms?

I had learned over 22 years as a health-care provider that treating symptoms without addressing the root causes of an illness often led to worse problems later. On the other hand, if a patient and I could work together using basic principles of health to address the roots of their illness, we could bring about a new state of health, making it possible for that person's whole system to function at a higher level.

As I explored the damaged landscape around me, I started to wonder what a fully functioning and healthy landscape would look like, and what principles might be involved in restoring the function of a landscape and its watershed.

I was fueled in particular by my fascination with water. Where did all that water come from during that storm? Why didn't the soil soak it up? Why were some areas so much more affected than others? What were the effects of runoff on my own health when I jumped in the river after a rainstorm, or swam in a lake with an algae bloom?

These questions led to more questions, which the scientists, agronomists, and farmers around me were also trying to figure out: How do plants and microbes create soil structure that holds water? What are reliable ways to test changes in soil's health, structure, and function?

I became part of a monitoring project with a nonprofit called the Soil Carbon Coalition that was measuring changes in soil health and watershed function at innovative farms all around North America and teaching community members simple and effective ways to do the same.

In my travels, I got to see land in various stages of recovery. It was wonderful to see healthy farmland and rangeland, just as it was when I saw my patients return to health. Yet I also saw millions upon millions of acres of land that was "naked, hungry, thirsty, and running a fever" (in the words of Ray Archuleta of the NRCS). As I looked at the contrast between that degraded land and the lush, productive land that had been brought back to health, I saw an opportunity. I decided to create learning resources that would help future farmers, ranchers, and policy makers see possibilities for change and understand the principles that are being used to successfully restore health and productivity in many parts of the world.

I've always enjoyed teaching as a way of organizing and synthesizing what I'm learning. I tried out various activities in classrooms, with groups of farmers at agricultural conferences, and with friends at dinner parties. I organized materials for teachers, and started doing residencies at schools. Eventually I was invited to create a workbook on soil health principles for high school agricultural teachers in Oklahoma. With the help of many people, those first few activities grew into this manual.

I think these investigations will open up a new world for you, just as they have for me. A world of new and deepening questions, hopeful discussions, and meaningful actions. Most of all, I think these activities will provide opportunities for you to impact the future of your community.

In July of 2017, just as I was finishing this manual, another intense rainstorm swept through my town. This time I knew more clearly what I was seeing. The places where plant roots and other soil biology were alive and well served as large sponges that soaked up water while maintaining the integrity of their structure. The places where soil biology was not very active were washed away entirely. Just a few hundred feet from my house, in a dirt road, a gully opened up that was 8 feet deep, 20 feet wide and over a quarter of a mile long. There was no biology in the dirt road that could help hold the soil in place, and the soil was too compacted for water to soak in. On either side of the huge gully, grass, ferns, and trees were still growing happily, in intact soils. The healthy soil structure—which their roots and symbiotic microbes had created—had performed its natural function quite beautifully.

This scenario is playing out in various forms across the country and around the world. Much of our farmland is becoming as lifeless and compacted as that dirt road near my house. We lose topsoil at an alarming rate every season. Yet some places are gaining. We have much to learn from those farmers and ranchers.

May this book help you appreciate their work, as well as the work that is ongoing beneath their feet.

Didi Pershouse
August 2017

Why Study Soil Health and Watershed Function?

This manual focuses on soil biology's role in the water cycle: specifically, how soil organisms take sand, silt, and clay particles and use them to form a living sponge that soaks up, stores, filters, and slowly releases the water that is necessary for life on land. By using the principles of soil health, we can manage land in ways that support the plant, microbial, and other biological processes that create the fundamental infrastructure of life: the soil aggregate.

Long before the invention of agriculture, the earth's natural processes provided food and clean water for humans and other species. The invention of agriculture, while allowing for the creation of modern civilization, has brought with it a new set of challenges including increased erosion, runoff issues, and conflicts over water. In many parts of the world, flooding, drought, wildfires, and desertification are on the rise. In addition, some research would indicate that production levels for our major grain and oil seed commodities worldwide have reached a plateau, creating additional challenges in our ongoing struggle to feed and clothe the world.

Many of these challenges stem from the steadily decreasing water-holding capacity of agricultural soils as well as the inability of plants to efficiently access nutrients in the soil. These two issues are directly related to changes over time in soil biology, soil structure, and overall soil health. Our land management choices can dramatically improve this situation, once we understand how to support the work of other species in creating healthy functional soils.

By studying soil health principles, current and future farmers can learn to harness the power of biological work to help them achieve their agricultural goals while increasing clean water supplies, controlling erosion and runoff, and providing resiliency in the face of extreme weather events.

Goals for this Project

I have designed and tested this curriculum with certain goals in mind, both educational and social. These materials are designed to provide a foundation upon which participants can build:

- A basic understanding of the important (but invisible) biological work that happens throughout any functional landscape, and its connection to the water cycle
- Confidence and capacity to present these concepts to others and engage the community in larger projects—with some experience of how to engage others in fruitful and respectful discussions using shared listening time
- An increased sense of curiosity and hopefulness about the changes our world is going through
- An increased sense of agency in managing *processes* in agricultural and other landscapes: knowing the kinds of questions to ask in order to discover what is needed and how to tell if it is working

Participants can experience just the right context in which to develop all of the above as they learn the soil health principles, practice the skills necessary to observe and monitor changes in soil health and watershed function, and gain experience with decision-making and project planning while working toward a larger goal of a fully functioning landscape.

The investigations and activities in this manual can form the basis for projects in which teachers, students, and their communities learn how to:

- Approach complexity in agricultural systems by looking at relationships between physical, chemical, and biological processes within whole landscapes
- See opportunities and set realistic goals for functional change on a piece of land (faster water infiltration rates, higher net profits, increased stability of topsoil, longer season of green growth, etc.)

- Work with natural processes to achieve those goals
- Work effectively in groups to synergize ideas, support each other's learning, and engage community members
- Practice the skills needed to collect and map baseline data and then monitor actual change over time in soil health and watershed function

My intent is that communities and classrooms working with these materials will become hubs—for idea and information sharing—that promote collaboration and ongoing project development between schools, the farming and ranching community, scientists, and conservation and watershed districts.

To get the full impact of this material, it is recommended that you go through this whole series of activities and investigations, even if you cut some of them short.

This will give participants multiple chances to absorb three large concepts:

1. Soil structure has a huge influence on the water cycle, which makes life on land possible for humans and other species.
2. Other species create soil structure through work that they do. Most of that work is done by plants and microbes and is easy to overlook.
3. Human decisions about land management dramatically affect other species' capacity to do their work. If we understand the work of other species, we can participate in it and have a positive impact.

This first edition of this manual is not comprehensive by any means. I have included resources at the end to help fill the gaps. With additional support I hope to create further learning resources on such topics as the economics of soil health; biology's role in temperature, weather, and rainfall; soil's role in the carbon cycle; systems-based decision-making in land management; and the impact of soil health on human health.

The manual will be updated frequently with additional resources and activities. Please check www.soilcarboncoalition.org/learn to make sure you have the latest edition.

A companion to this manual, called *Field Methods for Monitoring Soil Health and Watershed Function* with step-by-step instructions can be found here: http://soilcarboncoalition.org/learning/fieldmethods.pdf

Using These Materials for Project-Based Learning

This curriculum is designed to prepare participants for a final project, which could take many forms. The project should not be a surprise assignment that is sprung on them at the last minute; rather, participants should be given a chance to think throughout the learning process about what they might want to do, how the material they are learning will be used to complete these projects, and how these projects will demonstrate their understanding of the learning goals and educational standards. The facilitator can help participants plan for success in their projects by keeping their awareness on the project and by connecting each of the investigations back to the project. Ideally, teams within the larger group will work on a variety of projects so they can synergize their efforts.

Project-based learning can provide many benefits:

- Participants are more likely to deepen their understanding, retain learning, and be more engaged when they get to put learning into action in a meaningful way.
- There are opportunities everywhere to improve the health and function of the land. Well-planned small projects can show others what is possible, and inspire larger initiatives.
- Young people are uniquely positioned to bring in new ideas in a non-threatening way—giving a talk at the local Grange or Rotary Club, or engaging family and

Examples of Interconnected Projects

- Create a public presentation or video for community members explaining soil health principles and the impact of soil health on watershed function.
- Invite the NRCS Soil Health Team to do a rainfall simulator demonstration for the community and let students explain what is happening and why.
- Create a restoration management plan for a place nearby. This could involve creating a rain garden to soak up rain off of a roof that is puddling nearby; improving infiltration rates or length of green season in a playing field; coming up with a plan to decrease erosion at the edge of a parking lot; or working with a local farmer to improve soil health on a corner of a farm through cover cropping, integrating animal impact, or some other means.
- Invite younger students to come to your classroom for a few days and pair them up with your students taking the role of mentors, while working on any of these projects.
- Work to engage the school or community in a larger initiative toward improving local soil health and watershed function.
- Have participants use the skills they have learned to do baseline and/or follow-up monitoring of a specific area under a restoration management plan so that they, or future participants, can assess change over time.
- Upload observations and monitoring results to the www.atlasbiowork.com public database to preserve observations for the community's future use.

neighbors to help them plan and carry out a project.

- Soil biology's role in water, carbon, and nutrient cycles is a cutting-edge subject, and projects can often lead to career opportunities. Two of my first soil-health students were invited to speak about soil aggregate structure and how it impacts water flows at an international conference on water. Their simple but powerful presentation was so well received that they made many important connections with the scientists and other leaders, and their video continued to be shown at other conferences by a leading soil health speaker.

Rainfall Simulators

Whatever projects your group chooses, I strongly recommend inviting the NRCS Soil Health Team (or your regional USDA Climate Hub) to bring a rainfall simulator to your class. These setups use actual soil samples from area farms. Participants can see firsthand how well soils under different types of management soak up rain and prevent runoff and erosion, based on watching the clarity and quantity of water flowing down through, and running over the top of, each soil sample. Learners can also benefit from designing their own rainfall and erosion simulators out of simple materials. See more details in the **Resources** section.

In the example shown below, soil and its ground cover from five different land uses were removed from fields and placed in pans. From left to right, the ground cover is reduced from sod with near 100 percent cover to conventional tillage with near 0 percent cover. The pans have holes in the bottom to collect infiltration and chutes out front to collect runoff. Water is sprayed over the pans to simulate rain. If you look at the collection jars, you can see that the tilled ground on the far right has 100 percent runoff with lots of erosion and no infiltration. The no-till has little runoff or erosion and lots of infiltration. The pasture on the far left, with the live plants has no runoff or erosion and 100 percent infiltration. This demonstration (from the Madison County Soil Conservation District in Tennessee) shows that tillage, ground cover, soil organic matter, and living plants greatly affect infiltration, runoff, and erosion.

Some Ideas about Teaching This Material

We all have working models of how we think things around us operate—whether we are thinking about how to have a good relationship, how to build a house, how the digestive system works, or how soil and water impact each other. These models are based on what we have seen and heard from others, how we have been taught to think about things, and what we have observed and figured out ourselves. It is normal for our working models to change over time.

Working models are an important aspect of learning, as well as a useful way to assess a participant's understanding. *It is important not to belittle someone's current working model by telling them it is wrong, but rather to give them opportunities to adapt it, make it more sophisticated, and possibly set it aside and adopt a new working model as they learn.* This is the natural process of learning for young people and adults. Science, agriculture, economics, and even our understanding of history—these are a flow of working models that get adapted, refined, and sometimes radically changed over time.

Take the time to understand the working model that each person brings to these studies at the beginning of discussions, and then track how those models are evolving, for this is the primary method of assessment here. As participants frame their own new questions, participate in discussions, and create videos or other presentations, it will be clear to you how their understanding is deepening.

All people have some model of how a landscape or watershed works, because everyone lives in a landscape with water, whether urban, suburban, or rural. We have all experienced rain. My goal when teaching is to help people see their current model of landscape function, then allow them to hold on to it just firmly enough that they can gradually adapt it and add to its complexity.

This curriculum is designed to help participants develop a relatively sophisticated working model of soil biology's role in landscape and watershed function. It will not ask them to accept a pre-set group of best practices; rather, it will give them some principles they can use as a basis for innovation, as well as skills for testing the health and function of the land around them. This will give them a way to test the effects over time of their own land management decisions as well as the results of regional policies. It will help participants learn to ask more meaningful questions, and give them some practice in answering those questions.

There are many wonderful examples of land managers, policy makers, and scientists who have changed how they see things, think about things, and do things as their own working models changed to include more parts of the whole. Give participants frequent examples of those people, and ask them to interview people working in soil health about how their understanding of the land around them and their actual practice of land management has changed over time. This will help participants become more responsible and resilient citizens with an ethic of lifelong learning. See the **Resources** section at the back of this workbook for some examples.

Building a Community of Natural Teachers and Learners

To effectively restore landscape and watershed function on a large scale, I believe we will need a generation of confident and innovative land managers who are lifelong learners and who are comfortable mentoring others.

If I want to provide participants with a sense of agency and interest, I make sure the learning process answers the following questions:

- What does this have to do with my life and the world around me?
- How are people using this in the real world?
- Is this something I can actually use?
- How will this help me build my career, contribute something meaningful to my family

and community, and have a higher quality of life?*

Every group has at least a few people who don't trust their own capacity to learn and think. These are ways I've found useful to re-establish a sense of self-esteem in learners of any age.

- Frequently appreciate the group *as a whole* for the effort they are putting in, rather than picking out individuals for praise.
- Get participants to ask their own questions, using the Question Formulation Technique. (See the wonderful book: *Make Just One Change: Teach Students to Ask Their Own Questions*, or visit www.rightquestion.org where you can download resources after filling out a short online form.) This makes a huge difference in a group's motivation and attention.
- Give participants an opportunity to apply their learning to actual issues that they can do something about.
- Frame questions that get participants to think about something *as a group* and build on each other's ideas. When everyone is thinking about something together, there are no wrong answers; e.g., "If we were going to accomplish X, what are your ideas of how we might do it? First I'd like to hear lots of ideas, even if you aren't sure whether they would work, then we will pick a few and build on them."
- Give frequent examples of farmers and others who had to overcome a struggle or failure and ended up doing something successful.

To develop listening skills and a desire to collaborate with others:

- Seat participants in a circle so they can see and listen to each other.
- At least once per class, ask a meaningful question that everyone answers in a circle, without interruption. Have a simple object that the speaker can pass along to the next person to signal that they are done speaking—it can be a different object each time.
- Make room for them to express their thoughts and feelings as part of the learning process.

To help participants build respect for each other and develop a sense of community at the beginning of the course, I recommend the following exercise. It may take a full class period or two, but the time you spend on this will be well worth it.

Ask everyone to answer the following questions, one at a time, without interruption—allowing a full go-round the circle for each question, one question at a time. The facilitator should answer the questions as well, when it comes to you.

- Introduce yourself.
- What is the worst possible outcome of this class?
- What is the best possible outcome of this class?
- What beliefs and behaviors are most likely to lead to the best possible outcome?
- What advice do you have for yourself, and for us as a group, about strategies and actions we could take to make the best possible outcomes more likely to happen?

To help participants take charge of their own learning process, it is often helpful to let them engage directly with the goals, curriculum design process, and learning standards themselves. Here are two examples:

- Let them know the goals of each investigation and ask them for input on how well the lesson design is moving them toward those goals, and how it might be improved. Tell them you will be sending me their input (and please do! I can be reached at landlisteners@gmail.com).
- Put each of the Crosscutting Concepts of the Next Generation Science Standards on an index card. After the end of an investigation, you can hand out the cards, have participants read them, and say whether or not they think the activity addressed that concept.

* For further reading on teaching students to think in systems and apply their learning to improving the conditions and function of the world around them, I suggest the following resource: http://sustainableschoolsproject.org/sites/default/files/EFSGuide2015b.pdf

Next Generation Science Standards Crosscutting Concepts

1. **Patterns.** Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.
2. **Cause and effect: mechanism and explanation.** Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.
3. **Scale, proportion, and quantity.** In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.
4. **Systems and system models.** Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.
5. **Energy and matter: flows, cycles, and conservation.** Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.
6. **Structure and function.** The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.
7. **Stability and change.** For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.

Uploading Data to a Public Map Database

Atlasbiowork.com is a "web app" for data entry around soil health and watershed function. It provides a free and fairly simple way to connect observations and measurements with photographs and site locations—for example with a smartphone—and for presenting these on maps. The database provides a reliable place to store student and community data from one year to the next so that incoming classes can build on meaningful multiyear projects, asking new and more complex questions, while having a growing set of baseline data to work with, in a format that matches their own. The app is designed by a nonprofit organization for regional or school-based citizen-science initiatives that want to encourage broad participation in tracking and understanding changes in land function.

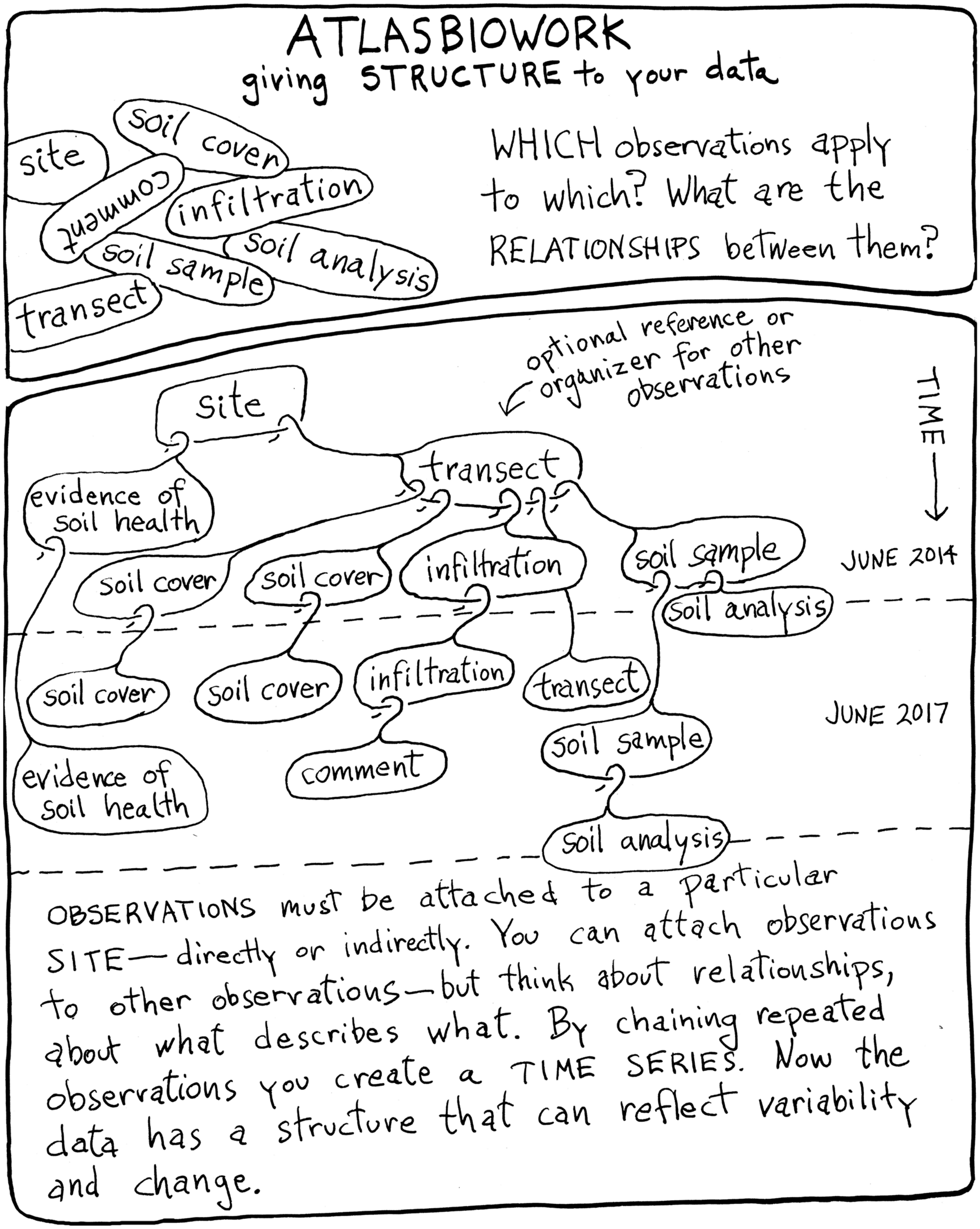
Web apps or web applications work in a browser such as Chrome or Safari, and on devices ranging from smartphones to desktop computers. Modern browsers can store data, including some photographs, while offline or off network, so it is possible to use web apps on mobile devices to collect data where there is no cell signal or Wi-Fi. Before you try to do this with atlasbiowork.com, you must choose ADD TO HOME SCREEN when you are connected online to atlasbiowork.com. Then you can open the app and collect data without a network connection. (If your connection is poor or intermittent, it may be best to turn your device to airplane mode to avoid confusion between online and offline modes.)

Mobile devices using web apps may encounter some limitations, but it's possible to do a good job of data entry. A spare battery, as well as a notebook and pencil for backup, are recommended.

The HOME screen is the start and menu for the app. Before you can post data or record an observation with atlasbiowork.com, you must be logged in. You may log in with your Google, Twitter, or Facebook account, or you may request a username and password from the Soil Carbon Coalition at info@soilcarboncoalition.org. In your first use of atlasbiowork.com, you will be asked to "Allow" your location to be passed to the app. You must click OK to record locations using your device's GPS or global positioning system.

All observations entered must be connected to a location or SITE. This is most often a point, with latitude and longitude coordinates, but it can also be a line or polygon. For a new point site, choose NEW POINT SITE + OBSERVATION and follow the prompts. Your device should locate you (if it doesn't have a GPS, the location will reflect the location of your network connection) and show you as a point on a map. You must choose a name for the site. When you select CONTINUE, you will see a menu of observation types to choose from.

To enter an observation for a site that has already been entered, visit the SITES list from the main menu. You can select the site from the list, or from the map, or from another observation on the site. Choose ADD OBSERVATION.


ATLASBIOWORK
giving STRUCTURE to your data
site
soil cover
comment
infiltration
soil analysis
soil sample
transect
WHICH observations apply to which? What are the RELATIONSHIPS between them?
optional reference or organizer for other observations
TIME
site
transect
evidence of soil health
soil cover
soil cover
infiltration
soil sample
soil analysis
JUNE 2014
soil cover
soil cover
infiltration
transect
JUNE 2017
comment
soil sample
evidence of soil health
soil analysis
OBSERVATIONS must be attached to a particular SITE—directly or indirectly. You can attach observations to other observations—but think about relationships, about what describes what. By chaining repeated observations you create a TIME SERIES. Now the data has a structure that can reflect variability and change.

Soil Health Principles

(This is my expanded version of the USDA-NRCS Soil Health Division's short list of soil health principles, with more explanation.)

- Much of soil life is fed by liquid carbon produced by photosynthesis, exuded through living plant roots. **Keep living roots in the ground as long as possible.**
- Soil life needs protection from heat, pounding rain, and wind. **Keep soil covered year-round.**
- A diverse system is more resilient than a monoculture. **Use plant diversity to increase diversity in soil microorganisms, beneficial insects, and other species.**
- Soil life is hard at work building underground structures we depend on for water, carbon, and nutrient cycling, and for structural stability for our own infrastructure. **Try not to disturb those underground structures with tillage.**
- Like any other living system, soil ecology will succumb to overwhelming stresses. **Minimize chemical, physical, and biological stresses.**
- A healthy landscape stores and filters water, cools the surrounding atmosphere, creates mist and clouds, and prevents flooding and drought. Complex systems involving all kingdoms of life are responsible for the water cycle on land. **Plan with the whole water cycle in mind.**
- Nature never farms without animals. Animals move nutrients, create small and large pores in soil, manage flows of water, pollinate crops, balance predator/prey relationships, and replenish soil microbes. **Plan to integrate and welcome a diversity of animals, birds, and insects into the system.**
- Every place has unique strengths and vulnerabilities. **Get to know the context of the land.**

Soil and *Water* INVESTIGATIONS

What Changes Are People Noticing in the Water Cycle?

Participants research the impact of flooding, drought, and other water-related issues happening in a place that is meaningful to them, and report back to the class.

What Changes Are People Noticing in the Water Cycle?

EDUCATIONAL STANDARDS

Next Generation Science Standards

Performance Expectations:
HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
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.

Science and Engineering Practices:
Asking Questions and Defining Problems.
Constructing Explanations and Designing Solutions.

Disciplinary Core Ideas:
LS2.A. Interdependent Relationships in Ecosystems.
LS2.C. Ecosystem Dynamics, Functioning and Resilience.
LS4.C. Adaptation.
LS4.D. Biodiversity and Humans.
ESS2.A. Earth's Materials and Systems.
ESS2.C. The Roles of Water in Earth's Surface Processes.
ESS2.D. Weather and Climate.
ESS3.A. Natural Resources.
ESS3.B. Natural Hazards.
ESS3.C. Human Impacts on Earth Systems.
ETS1.A. Defining and Delimiting an Engineering Problem.
TS1.B Developing Possible Solutions.

Crosscutting Concepts:
Patterns.
Cause and Effect.
Systems, Stability and Change.

Common Core State Standards

SL.9-10.1. Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade-appropriate topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.
RI.11-12.7. Integrate and evaluate multiple sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a question or solve a problem.

National Council for Agricultural Education Standards

CS.01. Analyze how issues, trends, technologies, and public policies impact systems in the Agriculture, Food & Natural Resources Career Cluster.
CS.01.01. Research, examine, and discuss issues and trends that impact AFNR systems on local, state, national, and global levels.
CS.04.02. Assess and explain the natural resource related trends, technologies, and policies that impact AFNR systems.
CRP.04.02. Produce clear, reasoned, and coherent written and visual communication in formal and informal settings.
CRP.04.03. Model active listening strategies when interacting with others in formal and informal settings.
CRP.05. Consider the environmental, social, and economic impacts of decisions.
CRP.08. Utilize critical thinking to make sense of problems and persevere in solving them.
NRS.01.04.02.a. Examine and describe the importance of groundwater and surface water to natural resources.
NRS.02.04. Examine and explain how economics affects the use of natural resources.

INVESTIGATION

What Changes Are People Noticing in the Water Cycle?

Time Required: 45–60 minutes discussion, 1–4 hours research and writing.

Summary: Participants pick a place that is meaningful to them and do some research about what changes people are noticing with the water cycle there. This research can be assigned as homework, or can be done while in the group setting, solo, or in teams of two or three. After completing their research, participants report back in writing, orally, or in a creative form, such as a video, poem, story, skit, poster, etc. After hearing each other's reports, participants will have a context for further study, with concrete examples of how water issues impact society, land systems, and the environment.

I strongly suggest that participants return to this research later in the learning process (at the end of the semester, workshop, or year) and answer similar questions to see how their understanding of connections between soil biology, water, and land management decision-making processes have deepened, and how their own feelings have changed. If the learning process is successful, they will have a greater sense of agency, and a greater vision of the possibility for change.

Goals

Participants will be able to:

- Describe qualitative and quantitative change in the water cycle and its effects.

Assessment: Participants will successfully prepare a report (written or creative), present the key details, and engage in a group discussion.

Materials:

☐ Worksheet: What Changes Are People Noticing in the Water Cycle?

Activity

Opening Question

› *What have you heard in the news in the past year related to changes in the water cycle?*

Write all the answers on the board.
Pick one or two examples and ask people a few of the questions from the worksheet.

Research Assignment
(Decide whether this will be an in-class or homework assignment, and how long participants should spend on it.)

Hand out the worksheet "What Changes Are People Noticing in the Water Cycle?"

Tell them they will be doing some research and coming back to the group with a report. Point out that the report should include *facts* from the research as well as their own *thoughts* and *feelings*. Suggest that they can be creative: they can write a report, but they could also compose a song, write a poem, create a skit, make a poster, or put together a short video or slide presentation.

➡ **Note:** If your participants are unlikely to take a creative risk on their own, you can assign it as a creative project; i.e., *"Everyone is going to do a skit . . ."* or *"Everyone is going to make a short video . . ."*

Tell them how long they will have to do the research.

Small-Group Discussion
After the research is completed, come back together.

If the group is large, have people break into groups of three or four.

Set a timer for two minutes, and have each person take two minutes to share what they learned from their research within their smaller group.

Large-Group Discussion
Have each person share their report, or if time is limited, have them share some highlights of what they learned with the larger group.

Assign a scribe to make a list of new words or concepts that people came across in their research, and write them on a large sheet of paper. Define them in class, or assign as homework.

Connecting the Dots

› *What social, economic, or environmental themes are you noticing that connect the various issues?*

Write the themes on the board. (Answers might include conflicts, expense of fixing the problem, political or cultural barriers to change, community-level organizing, academic research or citizen science attempts to quantify the issue, effects on human health.)

Wrap-Up

Ask participants to form a circle and take turns answering these questions:

› *What did you learn today and how do you feel about it?*

› *What new questions do you have?*

Have them take a sticky note or index card and write down their questions to give to you.

Important: Return to the Assignment Later

Ask participants to reread their initial reports near the end of the learning process (semester, course, workshop) and answer the following questions:

› *What new insights or information about this situation do you have since you first did this report?*

› *What new ideas do you have about how you might address this issue if you were in charge?*

› *Do you feel more or less hopeful about this situation?*

WORKSHEET

What Changes Are People Noticing in the Water Cycle?

Pick a place that is meaningful to you (somewhere that your family has connections to, a place where the culture is interesting to you, or you have always wanted to visit). Do some research about what changes people are noticing in the water cycle there.

Write, record, or videotape a news report that includes your *thoughts, feelings, research,* and *observations* related to the following questions. Feel free to be creative: compose a song, write a poem, create a skit, make a short video, poster, or slide presentation.

Describe the change

1. What is happening? What changes have people noticed? Give actual numbers to describe the quantitative change.

Describe the implications

2. How is the change affecting people and other species?
3. How would you feel if you were living in this situation?

Make some guesses about the cause

4. Why do you think this is happening? What is causing it?
5. How do you think people's decisions about land management are affecting this issue? Do you think they could be making better decisions?
6. Do you think this issue is connected to soil health or soil biology in any way? Make a guess as to how it might be connected.

Describe the response

7. What has the news media focused on? Do you think this is the right thing to focus on?
8. What kinds of strategies are people trying in order to address the situation? How well are those strategies working? How much would different proposed solutions cost?

Think about how would you deal with it

9. What do you wish you could understand more about this?
10. What steps would you take to deal with this if you were in charge?

Changes in the water cycle might include (but are not limited to) increases or decreases in things like:

- Flooding
- Rainfall, drought
- Clean drinking water
- Wildfires
- Runoff affecting rivers, lakes, or oceans.
- Toxic algae blooms
- Desertification
- Persistent humid haze or smog
- City storm drain issues
- Ocean rise affecting coastlines
- Soil erosion
- Water table levels, aquifers
- Conflicts over water usage rights

Flour vs. Bread: How Aggregate Structure Influences Water Flows

Using flour and bread as models of degraded versus healthy soils, participants do a hands-on exploration of what happens when water hits unaggregated versus aggregated particles.

Flour vs. Bread: How Aggregate Structure Influences Water Flows

EDUCATIONAL STANDARDS

Next Generation Science Standards

Performance Expectations:
HS-ESS2-5. Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.

Science and Engineering Practices:
Asking Questions and Defining Problems.
Developing and Using Models.

Disciplinary Core Ideas:
LS2.C. Ecosystem Dynamics, Functioning, and Resilience.
ESS2.A. Earth Materials and Systems.
ESS2.C. The Roles of Water in Earth's Surface Processes.
ESS2.E. Biogeology.
ESS3.B. Natural Hazards.
ESS3.C. Human Impacts on Earth Systems.
ETS1.A. Defining and Delimiting an Engineering Problem.
ETS1.B. Developing Possible Solutions.

Crosscutting Concepts:
Structure and Function.
Stability and Change.

Common Core State Standards

WHST.9-12.2. Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.
SL.9-10.1 and 11-12.1. Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on appropriate grades' topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.

National Council for Agricultural Education Standards

CS.06.01. Examine and explain foundational cycles and systems of AFNR.
CRP.05. Consider the environmental, social, and economic impacts of decisions.
NRS.02.02.01.c. Evaluate how the availability of natural resources can be improved through changes to human activity.
ESS.03.04. Apply microbiology principles to environmental service systems.
ESS.03.04.01.a. Describe the microbial biodiversity found in soil and summarize the contribution of microbial biodiversity to the physical and chemical characteristics of soil.
ESS.03.04.01.b. Assess how the activities of microorganisms in soil affect environmental service systems and ecosystem biodiversity.
ESS.03.02. Apply soil science and hydrology principles to environmental service systems.
ESS.03.05. Apply ecology principles to environmental service systems.

INVESTIGATION

Flour vs. Bread:
How Aggregate Structure Influences Water Flows

Time: 15–60 minutes, depending on the amount of discussion.

Setting: Indoor classroom or other indoor space. A sink is a big help!

Summary: If I only have time to do one activity with a group, this is my favorite one. Using flour and bread as models of degraded versus healthy soil, this exercise engages people in a hands-on exploration of what happens when water (or wind) hits aggregated versus un-aggregated particles. The main takeaway is that microorganisms and other living things are responsible for creating the structures and pore spaces of the "soil carbon sponge" that we depend on for the water cycle to function properly on land: giving us clean filtered water, protection against flooding and drought, .and a stable infrastructure for our civilization. (Parts 2 and 3 can be swapped if you like, and there are lots of additional activities at the end that can be added on.)

Goals

Participants will be able to:

- Describe and visualize how extreme weather events will affect healthy versus degraded soil.
- Picture healthy soil as a living, sponge-like structure covering the landscape that accepts, holds, and filters water, and maintains its structural integrity.
- Understand that sand, silt, and clay are the mineral portion of soil, and living organisms create soil structure out of those minerals.

Assessment: Completed worksheet with correct observations and reasonable hypotheses.

Materials

- ☐ White flour (if you have students with gluten allergies you may want to choose a gluten-free flour), approximately 1 cup for each team.
- ☐ Square loaf of sliced white bread, 2-3 slices for each team (gluten free if necessary).
- ☐ Paper cups (any size—but smaller is better so that people don't overdo it with the water!) 2 for each team. Make sure you can poke holes in them.
- ☐ Water available for each team—in water bottle or second cup.
- ☐ Toothpicks, or unfolded paperclips, to poke holes in cups.
- ☐ Large plastic plates, 2 for each team. (Make sure there is room to leave some space around the bread for water to flow without dripping off the edge.)
- ☐ (Optional) Paprika, for filtration experiment.
- ☐ Compost bucket for wet bread and flour at end.
- ☐ Worksheet: Flour vs. Bread.

- **Note**: At the end of this activity, you will end up with a lot of wet bread and wet sticky flour. It is helpful to have a compost bucket ready, and a plan for whether you are going to wash off the plastic plates to use them again, or just dispose of them.

Video Examples
Emaline's Demo of Water Infiltration:
www.youtube.com/watch?v=LLuWvekrnYw

Soil Runoff Dinner Party Demonstration Part 1:
www.youtube.com/watch?v=9aC9kynpVxk
and Part 2: www.youtube.com/watch?v=6ewiV19yJoQ

Activity

Part One: What Happens When You Pour Water onto Flour?

Hands-On

1. Put about 1 cup of flour in a small pile on a plastic plate for each team.
2. Tell them to imagine that this flour is soil.
3. Explain that the **substrate** (or base material) of soil is simply broken-down rocks. This is called the **mineral portion of soil**, referred to as "**sand, silt, and clay.**"
4. Hand out a cup with about an inch of water in it, plus a second empty cup, and a toothpick (or unfolded paperclip) to each team.
5. Have someone from each team poke about 10 small holes in the bottom of their empty paper cup, to create a "rain cloud."
6. Ask people to watch carefully what happens while one person holds the "rain cloud" over the flour and another person pours water into it so that it rains down onto the flour.

Observations

› Ask: *What do you see happening?*

Let the participants notice and describe as many things as they can; prompt if necessary:

› *Is the water soaking in?*

› *Where is the water going?*

› *Is the water that is running off clear?* (No, it has particles in it.)

› *What effect is the water having on the flour?* (Erosion is happening—creating gullies in the flour—and it is also sealing off the surface.)

Small-Group Discussion

Use worksheets, and/or discuss in small groups:

1. When rain water runs off the land, where does the water go?
2. If soil erodes, and the particles get washed away, where do the particles end up?
3. Why do you think the "soil" moved with the flow of water?
4. What would need to be different in order for the particles to stay in place?

Large-Group Discussion of same questions

Part Two: What is the Difference Between Flour and Bread?

Hands-On
Give each team a plate with two or three slices of bread piled up in a stack.

Engaging Question

› *Besides liquid, what is the one most important thing you have to add to flour to turn it into bread?* (Yeast.)

› *What is yeast?*

Brief Lecture: *Healthy soil is alive!*
Explain to participants that there are only three ingredients necessary to make bread: flour, water, and yeast. Yeast is a microorganism, a tiny living thing that does work. To turn flour into bread, you need biology—living things—to do that work.

A very similar thing happens with soil. Microorganisms and other living things turn mineral particles into a structured soil—with pore spaces.

How do they do that? All living things exude carbon-rich "snots, slimes, and glues." These are called **exudates**. We exude them when we are alive and also after we die. Usually these exudates are sticky. In healthy soil with lots of life in it, the exudates from fungi, bacteria, earthworms, and other living things help bind the particles of sand, silt, and clay together into **aggregates**, leaving **pore spaces** in between. This process is called **soil aggregate formation**. Thread-like root hairs and fungal hyphae help tie these smaller aggregates together into a porous spongy structure that holds and filters water and maintains its structure. We call that the **"soil carbon sponge."**

In actual soils, the particles are not made of flour; they are made of tiny pieces of rocks. The (nonliving) **mineral portion of soils** comes from the breakdown of rocks over time. The largest particles are **sand**, medium-size particles are called **silt**, and the smallest particles are called **clay**. It can take 1,000 years or more to form a single inch of sand, silt, or clay through weathering. Most soils have a mixture of these three in varying ratios.

Without contact with life, however, these particles cannot become soil. They are just particles of sand, silt and clay. (Some people call this dirt, rather than soil.) In order for these to become soil, they need to be in contact with living organisms, root hairs, **fungal hyphae**, and the exudates and remnants of living organisms ("the living, the dead, and the very dead"). Over time, the relationship between lifeless minerals and living organims creates living soil, or a soil carbon sponge. This soil carbon sponge is a living ecosystem, with many processes going on all at once, similar to the living tissue of animals.

We will talk more about the details later, but let's see what happens when water hits bread—flour that has been transformed by microorganisms into an aggregated porous structure. The bread is a lot like the structure of the soil carbon sponge.

Part Three: What Happens When You Pour Water onto Bread?

Hands-On

1. Put a stack of several slices of bread (with crusts cut off) on a second plastic plate for each team. Ask them to imagine that this is healthy, living soil.
2. Using the same cups, ask people to watch carefully what happens to the water when one person holds the "rain cloud" over the bread and another person pours water into it so that water rains down onto the bread.

Observations

› *What do you see happening?*

Let participants notice and say what they observe; prompt if necessary:

› *Is the water soaking in?*

› *Is it running off?*

› *Are the flour particles that are in the bread moving with the water or staying in place?*

› *If the bread were soil, would the rain reach the roots of the plants?*

› *If there were contaminants in the water, or on the surface of the bread, how well do you think they would be filtered out before they reached the bottom or got out to the edge of the plate?*

Group Shout Out

Ask this series of questions and let people call out the answers as a group. (The answer to all of them, except the last one, should be "THE BREAD!!")

› *If you lived in a place where it rained a lot every year and there was a lot of flooding, which kind of landscape would you rather have around your house, the flour or the bread?*

› *Let's say you lived in an area where it only rained a few inches every year and you were trying to grow food. Which kind of land would you want to be farming on, the flour or the bread?*

› *What if you got your water from a well? Which would fill the well better?*

› *What if you lived somewhere very hot and dry? Would the bread or the flour hold water better without it evaporating?*

› (I pick up a plate of flour that isn't completely wet, and hold it up, ready to blow on it . . .) *What if you lived somewhere VERY windy, like the prairie was during the Dust Bowl? What kind of land would you want around you, the flour or the bread?*

› *If your area was experiencing frequent earthquakes or tornados, which kind of soil would you rather have around you: more like the flour or the bread?* (I usually shake the two plates here.)

› *What if you were a fish in a lake, and people were using chemicals that were poisonous to you on the farms that surrounded the lake? Would those chemicals be more likely to be filtered out through the flour or the bread?*

› *If the water or soil became polluted with something hazardous, which landscape would be more likely to clean the water before it reached a well, stream, or lake?*

Small-Group Discussion

Use worksheets and/or discuss in small groups:

1. Why do you think the water entered the "soil" more easily this time?
2. Why do you think the "soil" stayed put this time?
3. What is different with the structure of the particles?
4. If you compare the bread and the flour, which one reminds you more of living tissue (such as that found in an animal or plant)? In what ways is (the bread) similar?

Large-Group Discussion

› *Is there any situation where you think the flour would be better?* (The only ones I can think of are some species adapted to living in relatively pure sand in a geological desert or coastal area, such as clams, turtles, etc.)

› *When water runs off the land, where does it go? What kinds of problems does runoff create?*

› *If soil erodes, and the particles get washed away, where do the particles end up? What kinds of problems does erosion create?*

› *What do you think you would need to do in order to create living soil out of degraded soil that has reverted back to mineral particles?* (We will cover this in the Soil Health Principles section.)

Part Four (Optional): "Raining" on Real Landscapes

Hands-On

Save the cups, and go outside with a gallon of water and "rain" water on various soil surfaces, such as loose soil at the edge of a parking lot, grassy areas, flower beds, school gardens, etc. Try digging up some grass, as well, and rain underneath it.

Observations

› *What do you notice?*

On worksheet, have participants mark down which places were more like flour, and which were more like bread.

OPTIONAL ACTIVITIES

1. **Wind blowing onto bread vs. flour**
   For younger students, before pouring water, have students blow on the flour and bread (or take plates with flour vs. bread outside on a windy day). This can be useful when discussing the Dust Bowl.

2. **Creating a landscape with bread vs. flour**
   Using a water play table or a large, shallow plastic box, create a landscape with bread as the soil, leaving some space for "rivers" and "lakes." Rain onto the landscape and see what happens. Repeat using flour or very fine sand and see what happens. Do the rivers and lakes stay in place? What happens when there is a flood?

3. **Which one works better as a filter?**
   If the water or soil became polluted with something hazardous, which system (flour or bread) would be more likely to clean the water before it reached a well, stream, or lake? Put paprika or other particulate matter into the water and repeat the experiment.

4. **Raining onto hardened flour**
   Mix flour and water and leave out to dry in the sun. Repeat the activity to show how water moves on hardened desertified predominantly clay soils, in places like Africa.

5. **Raining onto compacted soil**
   How do you think driving heavy machinery over healthy soil would impact it? Squish the bread with your hand, and use a 5x magnifying loupe (available online from The Private Eye) to observe what happened to the pore spaces. Pour water over it again. What happens to the water? Does it run off? Do the particles of bread move?

Part Five: Moving Forward

Circle Questions

Ask all participants to take turns answering the following questions (or if time is short, ask them to write answers on a sticky note and put them on the board as they leave):

› *What did you learn and how do you feel about it?*

› *What new questions do you have, based on what you learned today?*

Keep track of the new questions, and use some of them to begin the next activity.

handout

WORKSHEET

Flour vs. Bread: How Aggregate Structure Influences Water Flows

Flour and Water

1. When rainwater runs off the land, where does the water go?
2. If soil erodes and the particles get washed away, where do the particles end up?
3. Why do you think the "soil" moved with the flow of water?
4. What would need to be different in order for the particles to stay in place?
5. What would need to be different in order for the water to soak in to the flour?

Bread and Water

6. Why do you think the water entered the "soil" (bread) more easily this time?
7. Why do you think the "soil" stayed put this time?
8. What is different with the structure of the particles?
9. If you compare the bread and the flour, which one reminds you more of living tissue (such as that found in an animal or plant)? In what ways is it similar?

Comparing Flour and Bread

10. If you lived in a place where it rained a lot every year and there was a lot of flooding, which kind of landscape would you rather have around your house, the flour or the bread? Why?

11. Let's say you lived in area where it only rained a few inches every year and you were trying to grow food. Which kind of land would you want to be farming on, the flour or the bread? Why?

12. What if you got your water from a well? Which would fill the well better? Why?

13. What if you lived somewhere very hot and dry? Would the bread or the flour hold water better without it evaporating? Why?

14. What if you lived somewhere VERY windy, like the prairie was during the Dust Bowl? What kind of land would you want around you, the flour or the bread? Why?

15. If your area was experiencing frequent earthquakes or tornados, which kind of soil would you rather have around you: more like the flour or the bread?

16. What if you were a fish in a lake, and people were using chemicals that were poisonous to you on the farms that surrounded the lake? Would those chemicals be more likely to be filtered out through the flour or the bread? Why?

17. If the water or soil became polluted with something hazardous, which landscape would be more likely to clean the water before it reached a well, stream, or lake? Why?

18. Is there any situation where you think the flour would be better? Why?

Outdoors

If soil that is like flour is all the way on the left, and soil that is like bread is all the way on the right, write down each place you tried "raining" on, somewhere along the following scale:

More Like Flour More Like Bread

Monitoring Change in Water Infiltration Rates

Participants learn to monitor changes in soil health through land's ability to soak up water. This includes a review of math for calculating water volume, a discussion of factors influencing water infiltration times, and practice recording and uploading data to an online database.

EDUCATIONAL STANDARDS

Next Generation Science Standards

Performance Expectations
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-ESS2-5. Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.
HS-ESS3-4. Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

Science and Engineering Practices
Asking Questions and Defining Problems.
Using Mathematics and Computational Thinking.
Planning and Carrying Out Investigations.

Disciplinary Core Ideas
ESS3.C. Human Impacts on Earth Systems.
ESS2.E. Biogeology.
ESS3.B. Natural Hazards.

Crosscutting Concepts
Patterns.
Cause and Effect, Mechanism and Explanation.
Scale Proportion and Quantity.
Energy and Matter: Flows, Cycles, and Conservation.
Structure and Function.
Stability and Change.

Common Core State Standards

HSG.MG.A.1. Use geometric shapes, their measures, and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder).*
HSG.MG.A.2. Apply concepts of density based on area and volume in modeling situations (e.g., persons per square mile, BTUs per cubic foot).*
HSG.MG.A.3. Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios).*

National Council for Agricultural Education Standards

CS.06.01. Examine and explain foundational cycles and systems of AFNR.
CRP.07. Employ valid and reliable research strategies.
CRP.07.01. Select and implement reliable research processes and methods to generate data for decision-making in the workplace and community.
CRP.10.04. Identify, prepare, update and improve the tools and skills necessary to pursue a chosen career path.
CRP.11. Use technology to enhance productivity.
ESS.03.02.03.c. Conduct tests of soil to determine its potential for filtration of groundwater supplies and likelihood for flooding.
ESS.05.02. Perform assessments of environmental conditions using equipment, machinery, and technology.
ESS.01.02. Properly utilize scientific instruments in environmental monitoring situations (e.g., laboratory equipment, environmental monitoring instruments, etc.).
ESS.03.02.03.a. Examine and explain how the physical qualities of the soil influence the infiltration and percolation of water.
NRS.01.05.02.c. Interpret signs of habitat disturbances and resilience in an ecosystem and use these signs to assess the health of an ecosystem.
NRS.02.01. Analyze the interrelationships between natural resources and humans.
NRS.02.02. Assess the impact of human activities on the availability of natural resources.
ESS.03.02. Apply soil science and hydrology principles to environmental service systems.

INVESTIGATION

Monitoring Change in Water Infiltration Rates

Time Required: 4–6 hours.

Setting: An outdoor setting preferably with at least three differently managed soil systems where participants have permission to drive several short sections of pipe a few inches into the ground, pour water into them, and remove them. For example: the edge of a playing field, a school garden, an agricultural field, a bare spot in an area with a lot of foot traffic, a natural meadow, and a front lawn. (Forests can be interesting but also somewhat frustrating to work in, due to the number of large roots near the surface.)

Summary: The "ring" test for water infiltration serves as a useful visual demonstration for students to see the speed at which different soils absorb water under varying conditions—providing good fodder for discussion of actual land function in an outdoor setting.

Water infiltration testing is also a useful skill that is used widely by land managers and a variety of agricultural and environmental professionals for monitoring and mapping changes in soil health and soil structure and their impact on watershed function, water quality, and agriculture.

Start with a quick demo of an infiltration test, then participants review some basic math skills to give them confidence at working with the measurements necessary to use hollow cylindrical monitoring equipment (such as infiltration rings and bulk density samplers) on their own. A discussion also gets participants to think about other natural systems, tasks, and careers that involve tubes, pipes, and fluid measurements and dynamics (human and plant physiology, soil pores, artesian wells, medicine, plumbing, oil and gas industry, etc.)

Participants then learn the physical skills necessary to perform infiltration tests independently, what to do in some typical challenging circumstances, and how to record data both on paper and in an online map database. They create an instructional video as part of the assessment.

This unit also provides an opportunity for participants to practice uploading their own data to an online citizen science database.

Goals

Participants will be able to:

- Perform a ring test for water infiltration, using the tools properly, without guidance.
- Do basic calculations necessary for making and using their own infiltration rings.
- Interpret signs of disturbance and resilience in an ecosystem (soil disturbance, soil cover,

plant diversity, signs of insect activity) and use them, in combination with water infiltration testing, to assess the health of an ecosystem.

- Upload geolocated data on water infiltration to a public database.

Assessment

1. Participants record water infiltration data accurately on paper and in an online database.
2. Participants work in pairs to videotape a demonstration showing how to correctly perform a water infiltration test.
3. (Optional) Participants explain:
    - Complicating factors in interpreting results.
    - General significance of their results, and how they think it relates to soil structure and texture.

Materials

For group as a whole:

- ☐ One or more graduated cylinders or measuring cups with milliliters as a way to measure the equivalent of 1 inch (or 2.54 cm) of water.
- ☐ Sharp scissors (or knives) to cut plastic water bottles into portable measuring devices.
- ☐ Indelible markers to write on water bottles.
- ☐ Flat file for sharpening beveled edge of infiltration rings.
- ☐ At least one soil moisture probe of reasonably good quality; for example Vegetronix in Utah makes one for about $89.
- ☐ (Optional) Soil temperature probe (meat thermometers work well, though only in the top few inches) to correlate soil temperature with soil moisture and evaporation.
- ☐ (Optional) Rain gauge as a way of tracking recent rainfall and correlating it with soil moisture percentage and infiltration rates.

For participants to practice calculations for water in rings:

- ☐ Calculator.
- ☐ Worksheet: How Much Water to Use in Your Infiltration Ring.
- ☐ Pipes and infiltration rings with various diameters, several of each diameter (see below for details).

To do water infiltration testing, each team needs:

- ☐ Short Instructions: Water Infiltration Testing.
- ☐ Field Data Sheet: Water Infiltration Results.
- ☐ Infiltration rings of the same diameter, at least three per team: These are 6-inch-long sections of metal pipe, 5 or 6 inches in diameter (4-inch diameter rings will work, and are easier to get in the ground for some folks, but the accuracy decreases with the size). These should be approximately 1⁄10 inch (1.5 mm) in thickness, or about U.S. 12-gauge. (Steel is

best for all-around use. For routinely soft soils, aluminum irrigation pipe can work. In very soft soils, a plastic 5-gallon bucket with the bottom cut off can substitute for several steel rings.) The NRCS Soil Health Team often has these available, and (like any that you make on your own) will need to be sharpened on a grinder in a machine shop. Alternatively, a machine shop can cut and sharpen some for you, or a local auto repair shop may be able to help you out. One edge should be beveled sharp at about 45 degrees with a grinder, and can be kept sharp with a file. You will need a single reference point on the circumference of each ring for measuring drop in water level: a welded seam will work, otherwise file a slight notch in the top edge.

- ☐ 15 cm (6-inch) steel rule with millimeter scale for measuring ring diameter, and depth to water surface.
- ☐ Hammer or mallet for driving rings into soil. A 4-pound "deadblow" hammer is best. A hand sledge also works well.
- ☐ A 12-inch piece of wood cut from a 2" × 4" or 2" × 6" to place between hammer and rings for driving into soil. These may split or break, so it's good to have replacements. (Old textbooks work in a pinch!)
- ☐ A serrated knife. In very heavy sod, it may be difficult to drive even a well-sharpened infiltration ring into the soil, which may just bounce with the blows. Cutting a slot in the sod with a serrated knife, using the infiltration ring as a pattern and guide, may be necessary.
- ☐ 3 or 4 gallon jugs of water, or a 5-gallon collapsible jug for transporting water to the site. For five 6-inch rings, plan on having at least 3 gallons available.
- ☐ Plastic bag or plastic wrap, about 12 inches square, for protecting the soil surface as you pour water from your measure.
- ☐ 16.9 oz plastic water bottle with premeasured water level marked on side as a way to quickly measure and then pour the equivalent of 1 inch (or 2.54 cm) of water into your infiltration ring. Facilitator or participants will need to figure out the exact amount of water appropriate for the diameter of your infiltration rings. See the "calculating an inch of water" exercise. *Just to give you an idea: a ring with an inside diameter of 6 inches will need about 15 ounces (441 milliliters) of water.*

For each team to record data:

- ☐ Mobile device for recording data, getting location, and taking photos. You may use the infiltration form at https://atlasbiowork.com on a mobile device, which records timings as well as other data.
- ☐ Backups in case technology fails:
    - ☐ Stopwatch.
    - ☐ Auxiliary battery for mobile device.
- ☐ Clipboard for worksheet.
- ☐ Pencil.

☐ A signboard such as a pair of 9 × 12-inch whiteboards tied together at one edge, for labeling photos,
   - ☐ with a dry-erase marker and a rag,
   - ☐ Alternatively, you can use a clipboard with paper and a sharpie marker.

Background

Infiltration is the process by which water on the ground surface enters the soil through the pores by the forces of gravity and capillary action. Large cracks and pores (if present) fill directly by the force of gravity and provide a reservoir for the initial flush of water to start entering smaller pores. Smaller pores take longer to fill and rely on capillary forces as well as gravity.

There are a LOT of different factors involved in infiltration, and many factors that influence the speed of infiltration, including the physics of how water molecules flow through different-sized channels with or against gravity, whether the soil biology (plants, microorganisms, animals) has been able to create pores and channels, chemistry of water moving past or clinging to soils, and climate (temperature and moisture affecting evaporation rates). Some specifics:

- Gravity.
- Capillary action.
- Soil texture.
- Porosity of soil (related to density, aggregate structure, compaction).
- Surface sealing versus open surface pores.
- Size of pores.
- Saturation (how much of the available pore space is already filled with water).

EXAMPLES OF FACTORS AFFECTING INFILTRATION RATES

Relatively permanent factors: gravity, physical properties of water.

Long-term factors: soil texture (relative percentages of sand, silt, and clay).

Medium-term factors: soil structure (biological influences on soil aggregation); percent organic matter; compaction; size of pores and cracks; presence or absence of plant cover; presence or absence of roots; tillage; cracking; surface crusting; animal and insect burrows.

Short-term factors: soil moisture and amount of recent rainfall, light surface sealing from silt entering pores.

Some of these factors are relatively stable and permanent (e.g., the physical properties of water). Others are variable: long term (soil texture), medium term (biological influences), or very short term (saturation from recent rainfall). These interact and influence each other in a variety of ways, and vary in unpredictable ways.

As we track changes in soil health, because the context is so complex and variable over time and place, we need to return to the same location to monitor, and we are looking for *trends,* and particularly *trends over time* in the specific location that we are monitoring. For water infiltration results to be significant, it is important to test more than one spot in the area you are monitoring

(5 or more infiltration rings spaced a few feet apart from each other will give you a better idea of the trend in that area than a single ring, which might be over an animal burrow, or a large rock affecting the rate).

Regular and thoughtful monitoring of infiltration rates in a particular area can show whether the soil is becoming more or less functional in its ability to soak up water. Is the land management creating or destroying the soil sponge? The results of this monitoring can help direct our decision-making as responsible land (and watershed) managers. Widespread monitoring of water infiltration can give a good picture of a region's changing watershed health, and can help identify land managers who are successfully reducing non-point source pollution, and reducing their dependence on external water sources and irrigation.

Water infiltration rates typically will improve dramatically from year to year when soil health principles are put into effect by use of cover crops, reduced or zero tillage, and any other practices that enable soil biology to create more aggregate structure and soil pores.

Activities

Part One: Quick Demo and Then a Discussion About Infiltration

Quick demonstration (video or outdoors)
Show participants a video of a ring test for water infiltration, or step outside and drive three rings into the ground to show them the basics before engaging in a discussion. The purpose here is not to teach them the specifics of *how* to do it, but simply to give them a picture of *what* they are going to learn.

Engaging with a discussion
Today we are going to learn one way to test water infiltration, or how quickly water on the ground surface enters the soil. This will give us an approximate idea of how easily the soil in that spot absorbs rain or floodwater (though it is not the same thing as the actual infiltration rate of rainfall, because we are pouring the water on all at once to make the test go faster, so we are increasing the pressure of the water on the surface, and reducing the amount of time the water has to infiltrate before more water molecules follow).

If we do a baseline, and then test it again in similar conditions, over the long term, we can get an idea of whether the soil structure and function is changing: whether water infiltrates more quickly or more slowly.

› *Based on what we have learned so far, why does it matter whether water infiltrates easily or not? What effect can slow infiltration rates have on a landscape, community, or farm? What effect can fast infiltration have?*

Let students discuss out loud, and help them connect it back to previous activities like Flour vs. Bread demonstration.

Possible negative effects of slow infiltration can include increased flooding and drought; drops in water table; conflicts over water resources; not enough water for crops, animals, or people; more issues with runoff, erosion, and non-point source pollution; toxic algae blooms leading to neurological problems; increase in local ambient temperatures; ocean rise from global loss of soil moisture. **One positive effect of slow infiltration:** in extremely sandy soils, a somewhat slower infiltration can hold more water at the root zone for plants.

Possible positive effects of faster infiltration rates: abundant clean water for crops, people, animals; flood resilience; increased health of all species; increased length of green season leading to increased food production and better natural regulation of local and regional temperatures through cooling effects from transpiration and soil moisture; prevention of ocean rise by holding more moisture on land; retention of topsoil.

› *Are these different in a sloping landscape versus a flat landscape?*

› *What sorts of things do you think would influence the infiltration rate?*

› *If you were testing five rings all within a few feet of each other, and water disappeared in 30 seconds in one ring and it took 10 minutes in four other rings nearby, what might cause that?*
(Two possibilities are: animal burrows, or infiltration ring rocked back and forth as it was driven into the ground, creating a large crack along the inside edge.)

› *Since you caused one of those, but the other was occurring naturally and one is an accurate reflection of the state of the soil before you started testing, which one would you redo?*

› *Given that there could be that much variability, do you think it would be a good idea to average your times, or note each one separately? Why?*

› *Which of those are things that land management can influence? Which are permanent or would change much more slowly?*

› *Certain factors will determine the amount of pore space that is currently available, versus space that is already filled with water. What are some questions we might ask to get a general idea of how much of the available pore space is already filled with water?*
(Allow participants to come up with ideas. If they need prompting you can say a couple of these:
- How much has it rained in the last few hours, or the last few days?
- How much irrigation water was applied?
- How much water has flowed over the soil from other places?
- How much water has evaporated due to recent temperature and humidity?
- How much water are the plants using?
- What is the current percentage of soil moisture?)

› *Do you think the ambient temperature and soil temperature could affect the soil moisture? In what way? How does soil stay cool in most natural landscapes?*

› *What are some other questions you could ask about the land management, and things you might want to notice as you look at that spot to clarify why the water is infiltrating at the rate it is?*

Part Two: Calculating an Inch of Water in Your Infiltration Ring

Materials for Part Two

☐ Infiltration rings, and other sections of pipes, several of each of various diameters (and lengths if possible).
☐ Rulers with metric and inches.
☐ Pencil and paper.
☐ (Optional) Calculator.
☐ Worksheet: Calculating How Much Water to Use in Your Infiltration Ring.

Background for Part Two
Simple infiltration testing typically involves pouring an inch of water into a section of a pipe that has been driven into the ground. When the NRCS Soil Health Team hands out pre-made infiltration rings, they tell you how much water to pour in, which is fine if you use their infiltration rings. But if your student has to work with an infiltration ring of a new diameter—let's say you make your own out of some irrigation pipe you have lying around—how does she or he calculate the volume of that inch of water to know how much to pour?

Fluid fills and moves through tubular structures in many places: plant tissues, human anatomy, soil pores, irrigation pipes, and wells. Knowing how to calculate diameter, radius, area, volume, and conversions between milliliters and fluid ounces is important when monitoring soil health and watershed function. Reviewing this math will give students more of a sense of confidence with their tools as they start monitoring. Getting comfortable with applying these math skills to an actual task can also provide a basis for curiosity and confidence about approaching more advanced fluid dynamics that occur in soil, plant physiology, and watershed function.

Here is a quick overview of the math, but I'd recommend trying the worksheet yourself as the facilitator before beginning. The essence is this: *to calculate the equivalent volume of one inch of water in a hollow cylinder, you multiply the cross-sectional area of the cylinder (pipe/infiltration ring) by 1 inch, and convert the answer (which will be in cubic centimeters or cubic inches) to a fluid measurement (milliliters or fluid ounces).*

> **Metric example:** A round section of pipe has an inside diameter of 14.8 centimeters. The radius is half that: 7.4 centimeters. Using the formula πr^2 to get the area, and then multiplying that by 2.54 cm (the metric equivalent of 1 inch of water), we find that $3.14159 \times 7.4 \times 7.4 \times 2.54 = 437$ cubic centimeters. Cubic centimeters are the same as milliliters. So the amount of water you will need to measure in order to pour an inch of water in your infiltration ring is 437 milliliters. Many measuring cups no longer have milliliters, so if you don't have a metric measure, you can convert that 437 milliliters to ounces by dividing it by 29.6. (1 fluid ounce = 29.6 milliliters.) This gives you approximately 14.8 fluid ounces.
> **Imperial example:** That same round section of pipe has a radius of 2.91338 inches. Using that radius to calculate the area, $\pi r^2 = 26.6$ square inches. When multiplied by our depth of 1 inch, you get the same number in cubic inches: 26.6 cubic inches. Multiply cubic inches by .554 to get fluid ounces, thus our measure in this case should still be approximately 14.8 fluid ounces.

Engaging Participants
Tell them:

> If someone gives you an infiltration ring, they often tell you how much water to pour in, which is fine if you use their infiltration rings. But what happens if you

> have to work with an infiltration ring of a new diameter? Let's say you are travelling to do some monitoring and the airline lost the ones you made. You don't have time to order any, so you have to make your own. Maybe you go to a machine shop, or a place that makes oil drilling equipment, and get them to cut and sharpen some rings for you—how will you calculate the volume of that inch of water so you know how much to pour? The goal of this unit is for you to be able to work independently on monitoring projects, and be able to teach others. I want you to feel very comfortable and confident with these tools.

Many people zone out as soon as you start talking about math, even if it's a review of stuff they learned several years before. Others will perk up. I find these discussions work best if you put participants in charge right off the bat. Students who are more interested in people than in numbers will at least be interested in seeing how various other people are approaching it.

› *Let's see if we can figure it out as a group. There might be more than one way to do this, so let's take a few minutes to think about it and hear a bunch of ideas, before we decide as a group how we are going to do it.*

› *Turn to your neighbor and take turns thinking out loud. Raise your hand when you think you have an idea of a way to do it. You can build on each other's thinking.*

Allow participants time to share their ideas, one at a time. Appreciate people for their willingness to share their ideas, rather than for the quality of the answers (you'll be more likely to get a right answer from them next time!).

Ask if they are willing to come up and draw their idea so that those who like to think in pictures can see what they mean more clearly.
Who else has an idea?
How else might we solve this?

Challenge the more confident folks a little:
What if we had to do it in metric (or in inches)—how would that change the math?
Does that answer work for measuring fluids?
Does the length of the cylinder matter?

If someone does come up with a viable answer, don't jump in too quickly to say it's correct. (You may choose not to say it at all.) Allow time to let others share their ideas too, and let the group choose which answers they think will work. The group will often build on each other's ideas, and the discussion itself will give those who are intimidated some time to observe and think. The worksheet exercise will walk them through one way to do this, with two different measurement systems.

➡ **Note:** Some very practical folks will inevitably suggest something like this: *"Put a plastic bag inside the pipe, on a flat surface, stick a ruler inside, and pour water in up to an inch and then pour the* *contents of the bag into a measuring cup."* And in fact, this is one possible solution. Congratulate them on their practicality. (You can also tell them that the situation changed a bit and unfortunately they need to prove their answer was right with math, because the person who hired them is very fussy and doesn't trust their practical method. But, when doing the worksheet, let them use the extra time to try their method, and compare their answer with the other answers.)

Ask the group to come to some consensus about the methods they think are best—reminding them that there could be more than one. After a few minutes, either they will have chosen one or more reliable methods, or they won't. If they have not, then you can ask questions that will help direct them toward at least one reliable method, and remind them of some basic math concepts.

Do calculations with worksheet—in pairs

Once they have chosen a method that seems workable, have participants pair up, and then hand each pair a worksheet, an infiltration ring, and a ruler with centimeters and inches. Explain that this is one step-by-step way to do the calculations using math, and that they should remain open to trying other ways, as long as they can show their thinking. They are welcome to use extra time to compare this method with their method and see if the answers match up.

Make sure that several groups have the same size rings to help compare answers, but it is good if there are a few different sizes in the room overall, so that people don't assume their answer is going to be the same as everyone else's.

➡ **IMPORTANT:** You may come up with small variations in answers between groups using the same size rings, and also when shifting between metric and imperial. This variation is most likely due to subjectivity in reading the ruler's markings when measuring the diameter, not necessarily an error in calculations—check to see their starting measurements.

Additional options to practice calculations:

1. Try doing the calculations with some of the other methods they thought would work. Do they come out with the same numbers?
2. Try swapping with rings of a different diameter, and ask them to calculate again using one inch.
3. Ask them how much water they would need for two inches. Is it double? Why or why not?
4. If the diameter was doubled, can they double the amount of water? Why or why not?
5. Try calculating 6.3 centimeters worth of water, or some other random number.

What else can we do with what we learned?

Have participants pair up and think together about these questions, and then discuss as a group.

Have two people take turns writing people's ideas on big sheets of paper, or on the board.

› *Where else might you use these calculations?*

› *What other kinds of tasks or work involve pipes and tubes?* (oil industry, plumbing, automotive repair, medicine, etc.)

› *How many different natural and human-made things can you think of that have tubular spaces with fluid inside them in agricultural technology, or in plants or soils?* (e.g., culverts, irrigation pipe, hoses, stems, roots, fungal hyphae, pore spaces in soil, tubing, dug wells)

› *What might you need to calculate about those things, or in those types of work?*

› *What questions could you ask about the world around you that might use these calculations to find (all or part of) the solution?* (e.g., "My 3-foot-diameter well has 40 feet of water in it. How many gallons of water do I have left?")

Part Three: Teach Proper Technique for Doing Water Infiltration Tests

Short list of materials for Part Three

☐ Five rings.
☐ A 3–4 pound rubber mallet or "deadblow" hammer.
☐ A 12-inch long section of a 2" × 4" or 2" × 6" piece of wood.
☐ At least 3 gallons of water.
☐ A smaller clear plastic water bottle, top cut off, with a mark on the side showing the equivalent of what will be 1" of water in the infiltration ring (see instructions for calculating how many milliliters this is). (NOTE: not the same as an inch of water in the bottle!)
☐ A ruler with millimeters to record drop in 30 minutes for slow rings.
☐ A couple of 12" × 12" pieces of plastic wrap or a plastic shopping bag.
☐ A stopwatch or mobile device that will count up (if you have one for each ring, that will make things easier).
☐ A mobile device with a working GPS, or GPS app loaded.
☐ If you are using atlasbiowork.com for timing and/or uploading data, make sure that it is loaded on your device, and available to use even when offline.
☐ (Optional) Soil moisture probe and meter.
☐ (Optional) Soil temperature probe and meter.

Choose a spot where all participants can stand in a circle and watch as you demonstrate how to record data and do a ring test for water infiltration (see instructions below), as well as a soil moisture test and soil temperature test,(if you are including those).

Show participants how to record data

1. **Use the app.** Go to https://atlasbiowork.com, which will enable you to enter and save data with a smartphone or computer, although we recommend having backup options in case your mobile device's battery dies. Data entered via the app will be public, open, and mapped.
2. **Fill in the paper Field Data Sheet** "Water Infiltration Results" by hand as you do the tests. Technology can fail, and having a paper backup is always a good idea.
3. **Take a photo** that shows your rings as well as soil surface conditions and vegetation, using a signboard with site identifier and date.

Demonstrate infiltration test

The most important part of this demonstration is for participants to see the proper body mechanics to safely drive the rings into the ground, have a chance to try it themselves *with* supervision, and then try measuring and pouring water, starting timers, and practice setting their location and using the timers on the atlasbiowork.com monitoring app, while you are there to answer questions.

Ask participants to look over the rest of the data form, and see if they have questions, then talk through these steps while demonstrating.

1. **Select a location.** This could be a fairly uniform area in terms of soil cover, vegetation, or management, or it might be a transition between these. It is best to place rings within a meter or two of each other to make it easier to watch them, and to record an observation for a small area.
2. **Soil moisture and soil temperature readings.** If you will be doing the soil moisture and soil temperature tests, start by putting the soil moisture meter and temperature probe in the ground, and get a reading. Show students that you are recording the data on the data form, and have them look over the data sheets. Tell them that you will circulate to each team so they can do these tests during the water infiltration testing, unless your classroom can afford enough probes for each team to have their own.
3. **Place your rings on the ground, sharp edge down.** If rings are in an approximate line, such as along a transect tape, it is easier to keep track of the order and the timings. You may want to place rings on the variety of soil surfaces in the area that you have selected—such as bare soil, well-vegetated soil, average, and so on.
4. **Drive infiltration rings straight into soil with your hammer and wooden block.** In tougher soils and sods your rings must be sharp and you must swing that hammer in order to drive them in straight. Try to get them about halfway in (about 3 inches for a ring that is 6 inches long). You may firm the soil with your fingertips around the inside of the ring to take care of slight cracks from driving in the ring, but be careful not to disturb the rest of the soil surface, or the litter or mulch on it. In heavy vegetation it may be necessary to clip the vegetation in the ring area before driving in your rings.

5. **Place a plastic bag over the ring, push down the center enough to hold your inch of water, and pour in one measure (one inch) of water.** Slowly tug the plastic out from under the water and start your stopwatch. The purpose of the plastic is to protect the soil surface from scouring by your pour, stirring up sediment which can then settle in and plug the soil pores.
6. **Time the disappearance of the first inch of water**. Record the amount of time (in minutes and seconds) it takes for the inch of water to infiltrate the soil. Stop timing when the surface is just glistening. If the soil surface is uneven or sloping inside the ring, stop timing when half of the surface is exposed and just glistening. When litter or heavy vegetation is present, use a pencil or similar object to push plant matter aside so as to see whether there is standing water on the soil surface.
7. **Run an inch of water in the rest of your rings.** Unless the infiltration is very fast (under a minute or two), begin applying an inch of water to your other rings in order, using the https://atlasbiowork.com infiltration app to keep track of the timings. If using a stopwatch, start each ring at half- or one-minute intervals so you can use one stopwatch for all. For example ring 1 begins at 0:00, ring 2 begins at 1:00, ring 3 at 2:00, and so on. Just be sure you subtract the starting time from the finishing time for each ring in order to tally the elapsed time.
8. **Add subsequent inches of water.** After the first inch has finished, add a second inch, recording the timing. When that finishes, continue with a third and fourth inch similarly. The subsequent inches will generally take more time as more soil pores fill with water (and some collapse). After several applications of an inch of water, most soils will tend to approach a fairly steady value, reflecting its ability to keep its pores open and take water in a saturated condition.

Have students divide into teams of 3 to 4 people, and practice water infiltration testing and recording data.

This will work best if they aren't too far away from each other so you can float between teams and offer assistance. However, if teams can find differently managed soils within that area, that would be good. One team does the soccer field, one team does the school garden, one team does the lawn, etc.

Reflect and learn

1. Do you see connections or correlations between the condition of the soil surface (crusting, litter cover, vegetation, arthropod activity, etc.), and the speed of infiltration?
2. What might be the implications for runoff and surface water quality, groundwater or aquifer recharge, biodiversity both above and below ground, or production of food and fiber?
3. What about flooding and drought, or perceived drought?
4. If this is a re-measurement, what is the trend, and how might that reflect management of this land?

POTENTIAL ISSUES

If the water goes down very quickly (less than a minute) in one of your rings, and not nearly so fast in the others, it is likely that you have created a channel in the soil by rocking the ring back and forth as you pounded it into the ground. Or there may be a cavity, such as a soil crack or animal hole, under the ring. Note down the time, but also note that it seemed suspiciously fast. If you are only doing one or two rings, you might also want to redo that ring in another location.

In dry conditions, with shrink-swell or cracking clays, water may move in very fast through the cracks. If and when the cracks seal because the clay swells with water, the surface may become nearly impervious to water.

In very hard ground, such as dry, compacted hard clay, seriously rocky soils, or heavy sod, it may be difficult to drive rings halfway into the soil. In sod, cutting the sod with a serrated knife, using the infiltration ring as a guide, will help. Some soils may be difficult or impossible to test with these tools and methods. Do the best you can and note the fact that you haven't driven the rings very far in. Or come back when the soil is wetter and softer

If repeated applications of an inch of water do not result in slower timings, you may wish to "saturate" the soil in the ring with a generous dose of water, let it infiltrate, and try timing another inch or two.

If the first or second inch is taking over 30 minutes, record the drop in water level in 30 minutes as follows: 1) Add another inch if needed, and measure and record the vertical distance in millimeters between the lip of the ring and the water surface, at the seam or notch in your ring. 2) Set a timer for 30 minutes. 3) After 30 minutes, re-measure this distance, and record the difference in millimeters.

Wrap-Up

Have participants share the following:

› *What did you learn and how do you feel about it?*

› *What new questions do you have?*

Ask them to write their questions on a sticky note or index card and give them to you. Consider these questions to help guide your discussions in the next activity, and as possible starting points for final projects.

WORKSHEET

Calculating How Much Water to Use in Your Infiltration Ring

The essence of what we are doing is this: *to calculate the equivalent volume of one inch of water in a hollow cylinder, you multiply the cross-sectional area of the cylinder (pipe/infiltration ring) by 1 inch, and convert the answer (which will be in cubic centimeters or cubic inches) to a fluid measurement (milliliters or fluid ounces).*

METRIC (Milliliters)

1. The formula for the area of a circle is: πr^2 = area.

   The first step is to **calculate the radius.** The radius is the distance from the center of the circle to the edge. The diameter is the distance across the widest part of a circle.

   To calculate the radius, you measure the diameter, and divide it by 2:

   a. Use the metric ruler to measure the widest part of the inside of your infiltration ring to get the diameter.

   d = _______

   b. Divide the diameter by 2 and that gives you the radius.

   r = _______

2. Now that you know the radius, you can **calculate the cross-sectional area** (you can call this just the "area" to keep it simple).

   a. It won't work out right if you don't square the radius first, so do that now (multiply it by itself).

   r^2 = _______

   b. now multiply that answer by π.

   πr^2 = _______cm^2 This is your cross-sectional area.

   Area of your pipe is _______
   (hint: π = 3.14159)

3. Now we have the cross-sectional area, and we still need to **figure out the volume of water** that would be equivalent to the depth of water we want to pour in the pipe. Since you have been using metric so far, you need to convert that inch to centimeters.

   a. Convert your depth to centimeters:

   1 inch = _______ centimeters.
   (hint: 1 inch = 2.54 cm)

b. Now multiply the area (see above) by the depth of water you want (your inch converted to centimeters). This will give you a volume in cubic centimeters. (area × depth = volume)

area = ________ cm^2

depth = ________ cm

area × depth = ________ cm^3 (or cc)

volume = ________ cm^3 (cc)

c. Here's the easy part: *cubic centimeters are the same as milliliters.*
So, how many milliliters of water are you going to pour into your infiltration ring to get an inch of water in the ring? ________ ml

d. Here's the annoying part: Some measuring cups no longer have milliliters, they only have ounces, so if you don't have a metric graduated cylinder handy, you can convert those milliliters to fluid ounces by dividing them by 29.6. (1 fluid ounce = 29.6 milliliters.)

________ ml ÷ 29.6 = ________ fluid oz

If you are out in the field and don't have a graduated cylinder or a measuring cup, you can still probably find an empty water or soda bottle with fluid ounces on the label, and estimate your inch of water.

Okay, ready to do it in inches and ounces? Do you think this is going to be harder or easier?

IMPERIAL SYSTEM (Ounces)

1. The formula for the area of a circle is: πr^2 = area.

   So the first step is to **calculate the radius.** The radius is the distance from the center of the circle to the edge. The diameter is the distance across the widest part of a circle.

   To figure out the radius, you measure the diameter, and divide it by 2:

   a. Use the ruler to measure the widest part of the inside of your infiltration ring to get the diameter in inches.

   diameter = ________ inches

   b. Divide the diameter by 2 and that gives you the radius.

   radius = ________ inches

2. Now that you know the radius, you can **calculate the cross-sectional area** (you can call this just the "area" to keep it simple).

   a. It won't work out right if you don't square the radius first, so do that now (multiply it by itself).

   $r^2 =$ _______ square inches

   b. Now multiply that answer by π.

$\pi r^2 =$ _______ square inches. This is your cross-sectional area in square inches.
(hint: $\pi = 3.14159$)

3. Now we have the cross-sectional area, and we still need to figure out the volume of water in ounces that would be equivalent to the depth of an inch of water in the pipe. Since you are using inches, and you want one inch, this part is going to be a little simpler:

   a. Multiply the area of your pipe (see above) by the depth of water you want (1 inch). This will give you a volume of water in cubic inches.
   (area × depth = volume)

   area = _______ square inches

   depth = _______ inch

   volume = _______ cubic inches

Is your number in square inches the same as your number in cubic inches? Does that seem right?

Why or why not? ____

____

4. You are almost there! One cubic inch is equal to .554 fluid ounces. So multiply your volume of water in cubic inches by .554 to get fluid ounces.

   volume = _______ cubic inches

   volume × .554 = _______ fluid ounces

Using a measuring cup or graduated cylinder, pour that amount of water into a clear plastic bottle, set it on a flat surface, and mark the water level with a permanent marker.

This line is how far you should fill the bottle so you can pour an inch of water into your infiltration ring.

Now you have an easy-to-carry and unbreakable measure of one inch of water that you can bring out into the field with you for your infiltration ring. To make it easier to get water into it from a gallon jug, you can cut the top off, or even cut the bottle just a wee bit above where you marked it. Write on the side what diameter ring it is for, since an inch of water in a 5-inch ring will be different than an inch of water in a 6-inch ring, and you might work with different-sized rings. You may also use a can or other handy container with the correct volume marked on the side.

SHORT INSTRUCTIONS

Water Infiltration Testing

Materials Checklist

- ☐ Five rings.
- ☐ A 3–4 pound rubber mallet
- ☐ A 12-inch long section of a 2" × 4" or 2" × 6" piece of wood.
- ☐ At least 3 gallons of water.
- ☐ A smaller clear plastic water bottle, top cut off, with a mark on the side showing the equivalent of what will be 1" of water in the infiltration ring (see instructions for calculating how many milliliters this is). (NOTE: not the same as an inch of water in the bottle!)
- ☐ A ruler with millimeters.
- ☐ A couple of 12" × 12" pieces of plastic wrap or a plastic shopping bag.
- ☐ A stopwatch or mobile device that will count up (if you have one for each ring, that will make things easier).
- ☐ A mobile device with a working GPS, or GPS app loaded.
- ☐ If you are using atlasbiowork.com for timing and/or uploading data, make sure that it is loaded on your device, and available to use even when offline.

Place the rings and take a photo:

1. Place an infiltration ring on the ground on a flat spot (do NOT pull out the grass, but you can clip it if it is long).
2. Place the wood on top of the infiltration ring.
3. Pound the wood with your mallet until the infiltration ring goes *straight* into the ground about halfway, or 3 inches. If necessary, have someone else press down on the wood *with the heels of their hands* while keeping their head safely out of the way, to keep the ring steady while you hammer.
4. If the soil has pulled away from the inside edge of the ring, you will want to redo that ring in a different spot, and try to hammer a little harder and more in the center. If it's just a tiny bit of a crack (¼ inch or less) you can gently press the soil back into place.
5. Repeat with your other rings, choosing spots that represent the different surface conditions in the immediate area (e.g., do one in a bare spot, one in a spot with a lot of vegetation, etc.). Try to space the rings in a line not more than a few feet apart, so that you can keep an eye on them at the same time without walking a long way.
6. Decide which ring is ring number 1, 2, 3, etc. Be careful that you don't mix up which ring is which. Draw a little map, and number each circle.
7. Take a photo that shows your rings as well as soil surface conditions and vegetation, using a signboard with site identifier and date.

Test water infiltration times and record data

1. Place a piece of plastic wrap or a plastic bag suspended inside the ring, so that the edges are on the outside and can be held in place, forming a little cup hanging down inside for the water.
2. Have a stopwatch timer ready to start. If you are using atlasbiowork.com you can use the timers in the app.
3. Pour water from the gallon jug into your smaller container, up to the level you have marked.
4. Then pour (the equivalent of 1" water) from the smaller container into the suspended plastic wrap. Ask the person with the stopwatch to count down from 5, 4, 3, 2, 1 and then gently pull the saran wrap out so that the water reaches the ground.
5. Write down the start time. (For the first ring it will be zero. If you are using only one stopwatch, your next ring will likely be started while you are still timing the first one, so the next might be something like 2 min 12 sec.)
6. If they are going slowly, it's fine to start a new one before the first is done. If you do more than one at a time and you aren't using the atlasbiowork app, you'll need an extra timer, or you can note down when you start each new ring and then subtract that from the time it ends.
7. Keep an eye on the water, and note the time when it is no longer pooled, but the surface is glistening. You may have to move some grass aside to see if it is all gone. It is done when you no longer see any water. *If the ground is sloping or there are big clumps of soil inside making it very uneven, it is done when about half of the soil surface is visible.*
    - **If repeated applications of an inch of water do not result in slower timings,** you may wish to "saturate" the soil in the ring with a generous dose of water, let it infiltrate, and try timing another inch or two.
    - **If the first or second inch is taking over 30 minutes**, record the drop in water level in minutes as follows: Add another inch if needed, and measure and record the vertical distance in millimeters *between the lip of the ring and the water surface*, at the seam or notch in your ring. Set a timer for 30 minutes (or 15 if you are rushed). After the time has elapsed, re-measure this distance, and record the difference in millimeters.
8. Repeat steps 7–13 for your other rings, keeping an eye on any that are still going. Keep note of the start and end times for each ring. (Do not AVERAGE your times. Outliers are common.)

handout

FIELD DATA SHEET

Water Infiltration Results

Address and description of location: ____

GPS coordinates: ____

My GPS is accurate to within ___________ feet/meters (circle one).

What do you know about the current management here? (How often is it mowed, tilled, grazed? What grows here naturally, or what has been planted here? If it is in crop production, are cover crops used? For how many years? Are any amendments or chemicals being used here, such as compost, pesticides, herbicides, fertilizers, etc.? Which ones, how often, and for how many years?)

Is there anything you know about how this area has been managed in the past?

Are you uploading data to atlasbiowork.com? Yes/No

Are you testing the percent of soil moisture? Yes/No

If so, what depth are you testing, and what is the reading? ______________________________

Are you testing soil temperature? Yes/No

If so, what depth are you testing, and what is the reading? ______________________________

How many infiltration rings are you using in this spot?_________________________________

Did you photograph your rings once they were in the ground? Yes/No

Diameter of rings (measuring across the widest part): ______________ (centimeters or inches?)

Approximately how many inches of the ring's total length are underground? ________________

Draw where the five rings are in relationship to each other and number them on your drawing.

How many milliliters or ounces of water did you pour in each ring? ______ (Milliliters or ounces?)

Did you put plastic into the ring before pouring water? Yes/No

Did you make sure there were no large cracks that you created between the soil and the inside edge of the rings? Yes/No

Please fill in the times for the rings below, then answer these three questions:

1. Was there a significant difference between the infiltration times of your rings? Yes/No
2. Which ones were slowest? Why do you think these were slow?
3. Which ones were fastest? Why do you think these were faster?

Ring 1: What did you notice about the ground here?

1st inch Time started: ______________
Time ended: ______________
Total time in minutes and seconds: ______________

2nd inch Time started: ______________
Time ended: ______________
Total time in minutes and seconds: ______________

3rd inch Time started: ______________
Time ended: ______________
Total time in minutes and seconds: ______________
(Please keep going and note total times of any additional inches):

How many inches did you have to add till you got to a steady rate of infiltration? __________

What was that rate? ____

If the water was going down slowly, did you pour in an additional inch and record the drop over 30 minutes? Yes/No

Level when started: _____________ (inches/millimeters/centimeters? Circle one)

Level when finished: _____________

Ring 2: What did you notice about the ground here?

1st inch Time started: _____________
Time ended: _____________
Total time in minutes and seconds: _____________

2nd inch Time started: _____________
Time ended: _____________
Total time in minutes and seconds: _____________

3rd inch Time started: _____________
Time ended: _____________
Total time in minutes and seconds: _____________
(Please keep going and note total times of any additional inches):

How many inches did you have to add till you got to a steady rate of infiltration? __________

What was that rate? ____

If the water was going down slowly, did you pour in an additional inch and record the drop over 30 minutes? Yes/No

Level when started: _____________ (inches/millimeters/centimeters? Circle one)

Level when finished: _____________

Ring 3: What did you notice about the ground here?

1st inch Time started: ______________
Time ended: ______________
Total time in minutes and seconds: ______________
2nd inch Time started: ______________
Time ended: ______________
Total time in minutes and seconds: ______________
3rd inch Time started: ______________
Time ended: ______________
Total time in minutes and seconds: ______________
(Please keep going and note total times of any additional inches):

How many inches did you have to add till you got to a steady rate of infiltration? ___________

What was that rate? ____

If the water was going down slowly, did you pour in an additional inch and record the drop over 30 minutes? Yes/No

Level when started: ______________ (inches/millimeters/centimeters? Circle one)

Level when finished: ______________

Ring 4: What did you notice about the ground here?

1st inch Time started: ______________
Time ended: ______________
Total time in minutes and seconds: ______________
2nd inch Time started: ______________
Time ended: ______________
Total time in minutes and seconds: ______________

3rd inch Time started: ______________
Time ended: ______________
Total time in minutes and seconds: ______________
(Please keep going and note total times of any additional inches):

How many inches did you have to add till you got to a steady rate of infiltration? __________

What was that rate? ____

If the water was going down slowly, did you pour in an additional inch and record the drop over 30 minutes? Yes/No

Level when started: ______________ (inches/millimeters/centimeters? Circle one)

Level when finished: ______________

Ring 5: What did you notice about the ground here?

1st inch Time started: ______________
Time ended: ______________
Total time in minutes and seconds: ______________
2nd inch Time started: ______________
Time ended: ______________
Total time in minutes and seconds: ______________
3rd inch Time started: ______________
Time ended: ______________
Total time in minutes and seconds: ______________
(Please keep going and note total times of any additional inches):

How many inches did you have to add till you got to a steady rate of infiltration? __________

What was that rate? ____

If the water was going down slowly, did you pour in an additional inch and record the drop over 30 minutes? Yes/No

Level when started: ______________ (inches/millimeters/centimeters? Circle one)

Level when finished: ______________

How Does Nature Grow Food?
Using Soil Health Principles in Land Management

Participants work together to figure out the principles at work in productive natural landscapes, as an entry point to understanding the Soil Health Principles, then brainstorm all the agricultural practices they can think of that fit each principle.

EDUCATIONAL STANDARDS

Next Generation Science Standards

Performance Expectations:
HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

Science and Engineering Practices:
Engaging in Argument from Evidence.
Obtaining, Evaluating, and Communicating Information.
Constructing Explanations and Designing Solutions.
Asking Questions and Defining Problems.

Disciplinary Core Ideas:
LS1.A. Structure and Function.
LS1.C. Organization of Matter and Energy Flow in Organisms.
LS2.A. Interdependent Relationships in Ecosystems.
LS2.B. Cycles of Matter and Energy Transfer in Ecosystems.
LS2.C. Ecosystem Dynamics, Functioning and Resilience.
LS2.D. Social Interactions and Group Behavior.
LS4.C. Adaptation.
LS4.D. Biodiversity and Humans.
ESS2.A. Earth Materials and Systems.
ESS2.C. The Role of Water in Earth's Surface Processes.
ESS3.A. Natural Resources.
ESS3.C. Human Impacts on Earth Systems.
ETS1.A. Defining and Delimiting an Engineering Problem.
ETS1.B. Developing Possible Solutions.
ETS1.C. Optimizing the Design Solution.

Crosscutting Concepts:
Patterns; Cause and Effect.
Systems and System Models.
Energy and Matter: Flows, Cycles, and Conservation.
Stability and Change.

Common Core State Standards

SL 9-10 and 11-12.1. Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade-appropriate topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.
SL 9-10 and 11-12.4. Present information, findings, and supporting evidence, conveying a clear and distinct perspective, such that listeners can follow the line of reasoning, alternative or opposing perspectives are addressed, and the organization, development, substance, and style are appropriate to purpose, audience, and a range of formal and informal tasks.

National Council for Agricultural Education Standards

NRS.02.01. Analyze the interrelationships between natural resources and humans.
NRS.01.05.04.c. Devise a soil management plan to minimize erosion and maximize biodiversity, plant productivity, and the formation of topsoil.
CS.06.01. Examine and explain foundational cycles and systems of AFNR.
CRP.04.03. Model active listening strategies when interacting with others in formal and informal settings.
CRP.02.02. Use strategic thinking to connect and apply technical concepts to solve problems in the workplace and community.
CRP.05.02. Make, defend, and evaluate decisions at work and in the community using information about the potential environmental, social, and economic impacts.
CRP.06. Demonstrate creativity and innovation.
CRP.08. Utilize critical thinking to make sense of problems and persevere in solving them.
ESS.03.02. Apply soil science and hydrology principles to environmental service systems.
ESS.03.05. Apply ecology principles to environmental service systems.
ESS.03.05.01.a. Research the role that biodiversity plays in environmental service systems and how biodiversity can be measured.
NRS.01.04.02.c. Devise and apply strategies to manage, protect, enhance, or improve sources of groundwater or surface water based on its properties.
NRS.01.05.04.a. Compare and contrast techniques associated with soil management (e.g., soil survey and interpretation, erosion control, etc.).
NRS.02.02.01.c. Evaluate how the availability of natural resources can be improved through changes to human activity.

INVESTIGATION

How Does Nature Grow Food? Principles of Soil Health and Land Management

Time Required: 40–60 minutes.

Summary: Participants work together to figure out how natural ecosystems regulate water cycles and grow vast quantities of healthy plants and animals so effectively These group insights form the basis of a list of soil health and land management principles (which can later be tested and applied to agriculture, conservation, and other land management). The group's list is compared to lists of soil health principles that the Natural Resource Conservation Service (NRCS) Soil Health Team and other groups have been working on. See if they have come up with anything new to add to this effort. Then the group brainstorms all the agricultural and land-management *practices* they can think of for each principle.

Goals

Participants will:

- Understand that principles observed in natural ecological systems can be applied to improve resiliency and function of agricultural systems.
- Be able to describe ways that natural ecological systems successfully produce plant, animal, fungal, and microbial biomass without human inputs or management.
- Show an understanding of the Soil Health Principles by correlating them with related agricultural practices.

Materials:

- ☐ A whiteboard with markers, or some other way to take notes that everyone can see.
- ☐ Worksheet: How Does Nature Grow Food?
- ☐ (Optional) Slide projector and screen.
- ☐ (Optional) Slides or printed images of various natural versus agricultural landscapes (rainforests, prairies, or savannahs with large herds of grazing animals, ranches, and agricultural fields) in order to notice principles at work in different landscapes.

Part One: Introduction

Depending on the group, you may want to start with some version of this introduction:

A loosely organized group of people—many of them connected to the Burleigh County Soil Conservation District in North Dakota—have been working to understand the overall principles that allow natural ecosystems to grow healthy plants and animals so effectively.

We call these principles *Soil Health Principles* (or, as one farmer, Gabe Brown, says: "Nature's Way"). Many of these principles turn out to be a radical departure from the way we were taught to manage land, even though they can be observed all around us in the natural world. This has been a humbling experience for scientists, farmers, and other land managers, but also a very exciting one. Because of the work on soil health principles, farming has become a much more creative and exciting venture. Innovative people are applying these principles to farming and ranching, with excellent results: plants and animals get healthier, more resistant to diseases, and higher in nutrients; the land is less vulnerable to drought, flooding, erosion, and runoff; pest management is easier; and in many cases farm profits are increasing.

There is no single definitive list of these principles, nor should there be. People explain them and express them in a variety of ways. We are just at the beginning of understanding them, and we are still adding new insights.

Today we'll see if we can figure out some of these key principles on our own, and maybe we will come up with some new ones to add to the list.

We are going to think out loud together about how natural ecosystems grow healthy plants, animals, and people—and how that compares to the way that food is grown in most agricultural systems.

Part Two: Engaging Question

› *What are the most productive types of **natural** landscapes you can think of? (i.e., not farms or ranches)*

Participants may say some or all of the following:

- Rainforests
- Temperate forests
- Boreal forests
- Grasslands (also called prairies, savannahs, steppes, pampas, velds, or rangelands, depending on the region)
- Wetlands and marshes

› *Let's look at a tropical rainforest: Do you think a rainforest produces more or less total **biomass** (weight of* *living things: plants, animals, insects, fungi, microbes) both above and below ground, compared to a typical farm in that same climate?*

Explain that right now you are just going to estimate (a lot more, a lot less, a little more, a little less), but you could do a project where you calculate the biomass, or look up research others have done to calculate that biomass.

› *How about a natural grassland or prairie (before human intervention) versus a typical farm in Oklahoma or Kansas?*

› *How about a temperate forest versus a dairy or vegetable farm in New England?*

If you include everything, natural ecosystems will generally be far more productive in total biomass than farming systems. They will also generally provide far more ecosystem services in terms of water, carbon, and nutrient cycling.

As humans, we can't necessarily use all of that biomass, but everything that is produced in these systems is used by something else. Ultimately we benefit from this, even if we aren't using these products directly, because we are part of the whole system that cycles carbon, water, and nutrients through the landscape and atmosphere. Natural systems have evolved intelligent ways to hold and filter water; build carbon stores in soils and trees; balance predation by insects and animals; and regulate atmospheric carbon, temperature, and moisture.

Agricultural land, on the other hand, has tended to lose its carbon stocks (through deforestation, erosion, and loss of soil microbial communities); lose its natural water storage, water filtration, evapotranspiration, and rain cycling effects; and lose the balancing and regulating effects of complex ecosystem function. Because of that, agricultural land systems tend to become drier, compacted, more disease-prone, and less profitable over time, as well as increasingly dependent on technological fixes, with increasing costs for fertilizer, irrigation, pesticides, and disease control.

› *What can we learn from nature about how to grow large quantities of food that we can apply to farming and ranching?*

Part Three: Thinking Out Loud About Natural Versus Human Processes of Land Management

Challenge participants to come up with all the things that nature does to grow food—and to notice how these processes are similar to, or different from, current agricultural processes. Prepare to make a list on the board, with **Nature** on one side, and **Conventional Farming and Ranching** on the other side.

› *What questions could we ask each other in order to compare human versus natural systems for growing large quantities of foods?*

Write the group's questions on the board.

If you have a group that needs more prompting, here are some examples of questions you can add, that may help spark the discussion:

- *How do seeds get spread?*
- *How do seeds get into the ground?*
- *How are the plants arranged?*
- *Is the soil structure and ecology disturbed or left alone?*
- *Is the soil left bare or covered?*
- *How does water get to plants?*
- *How does water get to animals?*
- *What natural processes drive the water cycle?*
- *What species participate in the water cycle?*
- *Who spreads water over the landscape?*
- *Do natural systems tend more to monocultures or diversity of plant life? How about farms?*
- *How are nutrients returned to the soil?*
- *How are nutrients moved uphill?*
- *How does nature make sure falling rain seeps slowly into the ground rather than compacting it or eroding it?*
- *Who makes sure water gets down deep into the ground for deep rooted plants?*
- *How does nature prevent insects from eating plants?*
- *How does standard agriculture prevent insects from eating plants?*
- *How does nature (or agriculture) keep animals healthy?*
- *How does nature (or agriculture) make sure that the right food grows for the inhabitants who live in the area?*
- *How are soil temperatures modulated?*
- *How are ambient air temperatures modulated?*
- *Does anything cost money? What are those things? How much do they cost?*
- *Who pays for the cost of supplies?*
- *Does anything get damaged?*
- *Who pays for the cost of damages?*
- *What ecosystem services does each system provide?*

Go through the questions participants come up with (supplemented by this list) one at a time, and ask participants to think out loud, comparing the principles at work in natural systems with those in conventional farming systems. Write short versions of their answers on the chart so everyone can see them while you are discussing the differences. For example, for the question "How are seeds spread?" under **Natural Systems** you might write: "dispersed by wind, stick to animals' fur, carried in animals' digestive tracts, buried by squirrels…" and under "**Conventional Systems**" you might write "farm equipment, people working by hand."

If not everyone is participating equally you can use this rule: *"please don't speak twice until everyone who wants to share an idea has already had a chance to speak."*

I find this exercise tends to go better if you stay in a large group where the facilitator can keep the discussion moving and on track. However, if you want people to work in small groups first, you can hand out the worksheet "How Does Nature Grow Food?" and assign each group to discuss 4–6 questions (otherwise it can take a very long time.)

Part Four: Soil Health Principles

Remind participants that nature's processes for growing food developed through millions of years of adaptation.

› *Why do you think nature chooses to do things in this way? What advantages might there be?*

› *Which of these natural processes do you think helps to build the porous sponge-like structure of soil?*

Explain that now you are going to identify some of the key **principles** at work in nature that can be applied to agricultural systems. For example, in general, nature grows many different species of plants in a single ecosystem. This attracts a variety of pollinators, feeds a variety of beneficial insects, and creates a multistoried canopy that uses sunlight and catches rain from every angle. This efficient use of sunlight and rain allows the entire landscape to produce more biomass through photosynthesis, which in turn feeds more organisms that build soil structure for the plants. From all this, we could say that one key soil health principle would be to include a diversity of plants in an agricultural system.

› *What are some of the other principles you see at work in healthy natural landscapes that we could use in agricultural systems?*

Ask students to pair up and consider this, and then report back to the group. Write the group's answers on the board. Try to distill them (combining similar ones) and decide what effect they might have on a systems level, to see if they are key principles, or just practices. (See Part Five for examples of the difference between principles and practices.) You may need to help the discussion along by asking some leading questions, such as "Does nature plow up all the soil before planting seeds?"

Once you have a list, compare the list with this short version of the soil health principles from the NRCS Soil Health Team:

- Use plant diversity to increase diversity in the soil.
- Manage soils more by disturbing them less.
- Keep plants growing throughout the year to feed the soil.
- Keep the soil covered as much as possible.

Here is my extended version of these principles, with a bit more explanation of why I think they are important:

- Much of soil life is fed by liquid carbon produced by photosynthesis, exuded through living plant roots. **Keep living roots in the ground as long as possible.**
- Soil life needs protection from heat, pounding rain, and wind. **Keep soil covered year-round.**
- A diverse system is more resilient than a monoculture. **Use plant diversity to increase diversity in soil microorganisms, beneficial insects, and other species.**
- Soil life is hard at work building underground structures we depend on for water, carbon, and nutrient cycling; and for structural stability for our own infrastructure. **Try not to disturb soil structure with tillage.**
- Like any other living system, soil ecology will succumb to overwhelming stresses. **Minimize chemical, physical, and biological stresses.**
- A healthy landscape stores and filters water, cools the surrounding atmosphere, creates mist and clouds, and prevents flooding and drought. Complex systems involving all kingdoms of life are responsible for the water cycle on land. **Plan with the whole water cycle in mind.**
- Nature never farms without animals. Animals move nutrients, create small and large pores in soil, manage flows of water, pollinate crops, balance predator/prey relationships, and replenish soil microbes. **Plan to integrate and welcome a diversity of animals, birds, and insects into the system.**
- Every place has unique strengths and vulnerabilities. **Get to know the context of the land.**

What would you add to this list?
Please send us any ideas you have: landlisteners@gmail.com.

Part Five: Turning Principles into Practices

Explain that once land managers understand the key principles underlying soil health, they get to be very creative about how they put these principles into practice—sometimes even inventing new practices that are solidly based on known principles. Different contexts (climate, budget, goals, availability of materials and equipment, etc.) will also inform land managers' choices of practices. For example, the principle "Keep soil covered year-round" could be put into practice in a variety of ways, including planting cover crops, rolling down winter rye, or using mulch (made of bark, straw, newspaper, wool, etc.).

Ask participants to brainstorm examples of land management practices that put these soil health principles into action.

Here is an example of a list that one group came up with:

Principle: Keep living roots in the ground year-round
Practices: Living mulch, intercropping perennials between annuals, perennial vegetables and fruits, perennial polycultures and pastures, no-till, forest gardening.

Principle: Keep soil covered year-round
Practices: Cover crops, perennial crops, pasture, landscape cloth, mulch (straw, leaves, wood chips, newspapers), companion crops as living mulch, crop residue, rolling/crimping, pasture cropping, spring tillage instead of fall, succession planting.

Principle: Try not to disturb soil structure with tillage
Practices: No-till, low-till, perennial crops, pasture

Principle: Use plant diversity above ground to increase diversity in soil microorganisms, beneficial insects, and other species
Practices: Perennial polycultures, succession/companion planting, pasture cropping, mixed-species lawns with grasses and broadleafs, forest gardening, chaos gardens, silvo pasture, alley cropping, mixed-species cover crops.

Principle: Minimize physical, chemical and biological stresses
Practices: Use natural predators for insect control, mineral amendments, use nitrogen-fixing plants rather than adding chemicals, drip irrigation, soil cover to reduce impact of heavy rain, use organic versus synthetic fertilizers, wind breaks, pollination hubs/strips, hedgerows, mounded rows so that cold air flows down in winter, season-extension greenhouses.

Principle: Plan to integrate and welcome a diversity of animals, birds, and insects into the system.
Practices: Pollinator strips; hedgerows; chicken tractors; composted manure; ducks and mushrooms (ducks eat slugs); cover-crop grazing; pasture cropping; grazing buffers; silvo pasture; use goat, rabbit, and sheep manure directly on garden as cool manures; use goats and pigs for

managing invasives and clearing land; vermicomposting; use small pigs to turn compost piles; supporting earthworms, prairie dogs, snakes, dung beetles, etc., to increase soil macropores; aquaponics; living machines; integrating composted humanure and urine into farming.

Principle: Get to know the context of the land
Practices: Holistic management; check soil profile with shovel; monitoring, understanding "native" ecosystem and plant uses; cultural and historical context; current and historical animal, bird, fish, and insect migration routes and ranges; water flows, current and historical; tracking; know your keystone species; learn edible, medicinal, fiber, fuel plants in area; geology and soil types; walking borders, edges, collecting perennials to put in compost; find best and brightest native plants and pick a bit to add that microbial diversity to compost; seed microbiological diversity from perennial native, nondisturbed areas (like being animal vector); keep a journal of weather, rain, wildlife, growth, harvest, pests (e.g., "I harvested wild raspberries today"; "saw a Monarch today"; "it rained 3 inches").

Wrap-Up
Have participants share the following:

› *What did you learn and how do you feel about it?*

› *What new questions did this leave you with?*

Ask them to write their questions on a sticky note or index card and give them to you. Use those questions to help guide your approach to the next investigations.

WORKSHEET

How Does Nature Grow Food?

Make a chart or document comparing **natural landscape systems** versus **conventional farming systems**.

1. How are seeds spread?
2. How do seeds get into the ground?
3. How are the plants arranged?
4. Is the soil structure and ecology disturbed or left alone?
5. Is the soil left bare or covered?
6. How does water get to plants?
7. How does water get to animals?
8. What species participate in the water cycle?
9. Who spreads water over the landscape?
10. What processes drive the water cycle?
11. What are all the ways water gets deep into the ground for deep-rooted plants?
12. How does nature make sure falling rain seeps slowly into the ground rather than compacting it or eroding it?
13. How do nutrients and microbial life get into the soil? Are the microbes fed? How?
14. How are nutrients and microbial life moved around (and especially moved uphill)?
15. Do natural systems tend more to monocultures or diversity of plant life? How about conventional farms?
16. How does each system prevent insects and animals from eating plants?
17. How does each system keep animals healthy?
18. How does nature make sure that the right food grows for the inhabitants who live in the area? How does conventional agriculture get the right food to the people in each area?
19. How are soil temperatures modulated?
20. How are ambient air temperatures modulated?
21. Does anything in either system cost money—inputs, technology, etc.? What are these things? How much do they cost?
22. Who pays for the cost of supplies?
23. Are there any negative residual effects from the processes in either system? If so, who pays for cleanup, health costs, etc., from these effects?

25. What ecosystem services does each system provide? How valuable are these services? How would you assess their value?
26. What would the impacts be on human life if natural landscape systems failed? What would the impacts be on human life if conventional agriculture systems failed?

Can Biology Prevent Erosion?
Observation Hoops and the Soil Slake Test

Participants learn how to test water stability of soils by using a "slake test" (immersing soil clods in water). In the process, they learn that soil biology produces various binding materials (slimes and glues, root hairs, and fungal hyphae) that hold soil particles together in a porous but water-resistant matrix of aggregates during heavy rain and flood events. This powerful sponge-like structure prevents erosion and keeps waterways clean.

Can Biology Prevent Erosion? Observation Hoops and the Soil Slake Test

EDUCATIONAL STANDARDS

Next Generation Science Standards

Performance Expectations
HS-ESS2-5. Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.
HS-ESS3-2. Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.

Science and Engineering Practices
Asking Questions and Defining Problems.
Developing and Using Models.
Planning and Carrying Out Investigations.
Constructing Explanations and Designing Solutions.

Disciplinary Core Ideas
LS2.B. Cycles of Matter and Energy Transfer in Ecosystems.
LS2.C. Ecosystem Dynamics, Functioning, and Resilience.
LS4.D. Biodiversity and Humans.
ESS2.A. Earth Materials and Systems.
ESS2.C. The Roles of Water in Earth's Surface Processes.
ESS2.E. Biogeology.
ESS3.B. Natural Hazards.
ESS3.C. Human Impacts on Earth Systems.

Crosscutting Concepts
Structure and Function.
Stability and Change.

Common Core State Standards

SL 9-10 and 11-12.1. Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher led) with diverse partners on grade-appropriate topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.
SL 9-10 and 11-12.4. Present information, findings, and supporting evidence, conveying a clear and distinct perspective, such that listeners can follow the line of reasoning, alternative or opposing perspectives are addressed, and the organization, development, substance, and style are appropriate to purpose, audience, and a range of formal and informal tasks.
RST 9-10.7. Translate information expressed visually or mathematically (e.g., in an equation) into words.
RST 11-12.9. Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

National Council for Agricultural Education Standards

CS.06.01. Examine and explain foundational cycles and systems of AFNR.
CRP.05. Consider the environmental, social, and economic impacts of decisions.
ESS.03.04. Apply microbiology principles to environmental service systems.
ESS.03.04.01.a. Describe the microbial biodiversity found in soil and summarize the contribution of microbial biodiversity to the physical and chemical characteristics of soil.
ESS.03.04.01.b. Assess how the activities of microorganisms in soil affect environmental service systems and ecosystem biodiversity.
ESS.03.02. Apply soil science and hydrology principles to environmental service systems.
NRS.02.02.01.c. Evaluate how the availability of natural resources can be improved through changes to human activity.
NRS.02.05. Communicate information to the public regarding topics related to the management, protection, enhancement, and improvement of natural resources.

INVESTIGATION

Can Biology Prevent Erosion? Observation Hoops and the Soil Slake Test

Time: 20 minutes to several hours. (Simple demo can be done in 20 minutes; sample collection and discussion will take more time.)

Setting: An indoor or outdoor space where jars can be set up with access to plenty of water. (Indoors if you want to show some slides of erosion.) For sample collection: a variety of locations around the classroom, or in participants' neighborhoods, some with bare exposed soil and others with plant cover.

Summary: The soil slake test—in which samples of soil are immersed in water to see if they hold together or fall apart—has been popularized by Ray "The Soil Guy" Archuleta of the NRCS as one of the basic demonstrations of soil health. It is a wonderfully simple way for participants to see that soil life produces various binding materials (slimes and glues, root hairs, and fungal hyphae) that hold soil particles together in a porous but water-resistant matrix of aggregates during heavy rain and flood events. This powerful sponge-like structure prevents erosion and keeps waterways clean. This is a nice follow-up to the Flour vs. Bread investigation in which the concept of soil aggregation was introduced.

The unit starts with a discussion on erosion and its impact on humans and other ecosystems. After a short demo of a slake test, participants play with some biological slimes, then collect their own soil samples from a variety of differently managed areas. (Samples can be brought from other areas, and/or collected around a schoolyard or farm.)

As each sample is immersed in water, those with fewer biological binders will "slake off" into smaller particles and cloud the water, while healthy ones will stay intact and the water will remain clear. (These bonds can be so strong that soil will stay intact even after the water evaporates.) By comparing sample locations and results, participants will find that biological binders are more abundant in *undisturbed soils with living roots in the ground*. As they discuss the results, they apply what they learned to land management. What management choices would be likely to feed soil biology? How would they manage healthy land to prevent future erosion? This brings the discussion back to soil health principles.

The Connections section explores differences between **soil texture** (relative proportions of sand, silt, and clay) and **soil structure** (also known as soil health or soil function) and how they may interact to influence water flows. The section also gives information on how biological processes create **aerobic** and **anaerobic** areas in soils—both of which serve important purposes in the carbon cycle.

Goals

Participants will:

- Know how to use an observation hoop, perform a soil slake test, and be able to interpret the results in relationship to a particular soil's health and tendency to erosion.
- Be able to explain soil slake test results to others in ways that make the following three points clear: 1) Soils that hold together when immersed in water are less likely to erode and silt up waterways. 2) In a healthy soil, mineral particles are held together in water-resistant aggregates by biological binders including slimes, root hairs, and fungal hyphae. 3) Pore spaces between tightly bound aggregates provide areas where water can move freely without breaking the aggregates apart.
- Be able to draw soil aggregates and explain their structure and function as it relates to erosion.
- Show by example that undisturbed soils with more plant cover are less likely to fall apart in water than disturbed, bare soils.
- Be able to explain that humans influence erosion by land management choices that help create habitat, or destroy habitat, for soil organisms.
- Be able to recommend ways of increasing biological glues and other binders to prevent erosion in a familiar landscape.
- Be able to reasonably predict results of soil slake tests based on observations of land, and land management history.

Participants will keep asking:

- How do biological processes influence the water cycle?
- How can I improve the function of the landscapes around me?
- What land management strategies will lead to landscapes that are resilient in the face of flooding and drought?

Materials

☐ Wire snippers for cutting wire mesh.

For demo and each team:

☐ 1 trowel or shovel to extract soil samples.
☐ 2 containers to carry soil samples (pint-sized or larger plastic boxes or plastic bags).
☐ 2 wide-mouthed glass jars (quart or half-gallon wide-mouthed mason jars work well).
  ☐ OR: 2 tall (24 oz) *clear* plastic cups, such as those used for iced coffee.
☐ 2 pieces of ¼-inch wire mesh ("hardware cloth") cut to about 1½ × 6 inches (it should form a simple basket that hangs down in jar).
  ☐ OR: scissors *plus*
  ☐ 2 rubber bands *and*
  ☐ an onion bag, cut into 2 halves.

☐ Water to fill jars.
☐ 94" circumference observation hoop (a 94" section of plastic-covered 3⁄16-inch wire works best, easily available in most hardware stores).
☐ Clipboard.
☐ Pencil.
☐ Field Data Sheet: Observation hoop and sample collection for slake test (one for each sample).
☐ Worksheet Soil slake test observations and discussion.

For discussion of biological slimes and glues you might bring:
☐ Several decomposing mushrooms and root vegetables that have been stored in plastic long enough to get somewhat slimy.
☐ A few raw eggs.
☐ A slug or snail, if you can find one!
☐ Any other interesting biological slimes.
☐ Fine-quality sand from a sandbox, if you want people to play with combinations of mineral particles and slimes.

If you want participants to make a video of the process that explains what is happening as part of assessment:
☐ Video camera.

To save and upload geolocated data so participants can compare results and track change over time:
☐ Smartphone with camera, a functioning GPS, and https://atlasbiowork.com pre-loaded to easily upload photos to map. (This is best.)
  ☐ *Or* a smartphone with GPS app to track location of sample collection
  ☐ *And* a camera for photographing results.

Preparation: If you are going to do a demo of a soil slake test to begin the investigation, you should collect samples of soil from at least two distinct locations (enough soil for more than one clod from each place). Find one sample that stays very intact in the slake test (you might try several undisturbed grassy locations) and another sample that falls apart and makes the water very cloudy (from a disturbed area with no plant cover, such as the edge of a road or parking lot). Save "peds" (clods) from each of these locations to demonstrate with. Drying them on a dashboard or windowsill for 2–3 days will make the test more reliable.

Create two or more setups with a basket of mesh that hangs down into the clear mason jar or cup. The mesh should be low enough so that the clod can be fully immersed in the water, but high enough that there is still plenty of space below where participants can watch how much soil is falling and see the water getting cloudy or staying clear.

Video Examples of Slake Test:
www.youtube.com/watch?v=CEOyC_tGH64 Ray Archuleta Slake Test
www.youtube.com/watch?v=9uMPuF5oCPA Ray Archuleta Soil Stresses
www.youtube.com/watch?v=MOZi33vVsOA Nicole Masters Slake Test

Part One: Discussion of Erosion

One way to start this investigation is to get participants thinking about erosion. (You can also start straight in with a demo of the slake test, and then relate it back to erosion.) Having a slideshow with some dramatic examples of erosion will help with certain crowds.

Engaging with questions and a slideshow

› *What are your ideas about what the word "erosion" means?*

› *If you have taken a walk in the rain, where did you see erosion happening? Where was it not happening?*

› *Where have you noticed the effects of erosion?* (sloping fields, hillsides, soil that is not covered, sandy places, banks of some streams and rivers, mudslides)

› *When is it most likely to happen?* (when it rains or floods, also during high winds)

› *Do you think all soil is equally prone to erosion?*

Facilitator can show slides of different types of erosion in real landscapes to give participants a chance to see how extreme it can be. Point out that water erosion is a reinforcing feedback loop because of the physical properties of water and flows.

Brief lecture on physical properties of erosion

- Once gully erosion starts, it can be hard to stop. A small gully is likely to become a larger gully due to the combination of different principles in action:
- Water molecules have a *cohesive* quality (they stick to each other). This cohesive quality helps water molecules form into trickles, rivulets, streams, rivers, etc. Where one drop of water travels, the next one is more likely to follow, due to the *cohesive* quality of water molecules.
- These larger flows of water molecules can then push smaller particles of sand, silt, and clay by *force* and *gravity*.
- Water molecules also have an *adhesive* quality (they can stick to other things—like the inside of a drinking glass). This enables flowing water to stick to sand, silt, and clay particles as it moves by them, helping to pull them along with the flow.

Small-Group Discussion

Ask them to turn to each other and discuss the following question:

› *What would you need to do to overcome these forces to prevent erosion?*

This question will elicit a variety of answers. Have participants share their ideas. Accept them all and write them on a board.

Part Two: Demonstrate a Soil Slake Test to Show Biological Glues in Action

Most groups will appreciate a demo of the test before they go collect their own samples. If you are limited on time, this demo can serve as a substitute for participant sample collecting. (It is wise to collect a variety of samples in sufficient quantity to try out this demonstration ahead of time. To show a dramatic example, one sample should end up sticking together with clear water below it. The other should fall apart and cloud the water.)

The facilitator should have two jars ready to demonstrate a slake test, and two samples of soil, one (preferably rather hard and compact looking) from the edge of a parking lot without grass, or a heavily tilled field without a history of cover crops, and one from a grassy area or a no-till field using cover crops. Optimally these areas would be places with similar soil types, but different management. Try to remove most of the vegetation and roots from the sample with plant cover.

1. Let participants know where you got the samples, and how the land is being managed. Then ask them to make some predictions.

› *Look at these two soil samples. Which do you predict will fall apart faster in water? Why do you think that?*

› *Which do you think will make the water cloudier? Why?*

2. Give one sample to each of two participants, and ask each person to gently place their sample into the mesh in the jar filled with water, and ask them to observe.

› *What do you see happening?*

› *Have you ever seen something like this happening outside? Where? Under what circumstances?*

› *If you were to go back to the place where I got these samples during a heavy rain or flooding event, which one do you think would have more erosion? What would the land look like afterward? What would the streams or rivers look like?*

› *What other questions do you have?* (Don't try to answer the questions just yet, but by asking this, you will engage them in thinking more about what they are seeing.)

3. Ask them to think about what they are seeing, and relate it back to real concerns. Ask questions like:

› *Why do you think we are doing this test?*

› *What difference does it make whether soil stays together or not? Who benefits when soils stay together? In what ways?*

- *If you were buying land, can you think of any way this test would be useful to you?*
- *If you lived downstream from someone whose soil was like one of these two, what difference would it make to you? Does it matter if soil particles get into water?*
- *What issues can you think of that this test might relate to in farming, economics, human health, and environmental health? Why do people want to prevent erosion?* (loss of topsoil, farm profits, and land value; effect on water quality; environmental effects; effects on human health, etc.)

4. Find out what their working model is, and let them explore.
Ask them what they think is holding the soil together. Some participants may say "the roots." Acknowledge their answer, and say:

- *It's true that the roots are probably helping. Would you like to try it again and pull out any visible roots and break up the soil into small pieces?*

In this case, more particles will sink to the bottom, but the water should still be significantly clearer than the other one, even if you don't break up the other one. If you have other samples available, from different places, you might have them try a couple more tests. Ask them what they think they are seeing, and why the water remains clear even if you break up the clods.

5. Connect this activity with earlier knowledge.
Ask participants to think back to the Flour vs. Bread demonstration.

- *What connection do you see between this test and the Flour vs. Bread investigation?*
- *Which soil sample seems to have more resistance to the effect of the water—or to be coated with something hydrophobic?*
- *Does anyone remember how I described the way the mineral portion of soil changes from being separate particles to a sponge-like structure when soil has more life in it? What was involved? Who did that work?*

Part Three: Describe the Process of Soil Aggregation

Soil structure is created as mineral particles (sand, silt, and clay) are bound together into complex aggregated structures by various organic processes and substances. These are the "snots, slimes, and glues" exuded by all of life; the threadlike plant roots and fungal hyphae that stick to mineral particles and also bind the smaller aggregates together into larger ones; as well as the pathways of many sizes opened up as life moves through soil. These create spaces for all sorts of things to live, and all sorts of chemical, biological, and physical processes to happen.

- *Where have you seen natural slimes?*
- *Where do you think slimes come from in soil?*

› *What organisms or processes open air pockets and pathways in soil?*

› *Why is it important for soil to have air pockets and pathways in it?*

Some of the more important biological elements that help to create well-aggregated soils with high-functioning soil structure include:

- Healthy soils can have more than 25,000 kilometers of **fungal hyphae** per cubic meter. This includes **mycorrhizal fungi** that help plants access nutrients and water, and **saprophytic fungi** that help to decompose plant matter. The **chitin** that coats these hyphae eventually decomposes into a sticky glyco-protein called **glomalin**, which binds soil mineral particles together.
- As plants photosynthesize, they create sugars. A large portion of these sugars are exuded out from their roots to feed soil microbial life. The exudates themselves are fairly simple carbohydrate chains, and aren't particularly strong glues. However, they feed **mycorrhizal fungi** and **bacteria** that create lots of slimes and glues. The roots themselves also open pathways between aggregates providing spaces for air and water to flow as they decompose.
- Worms, ants, beetles, and other soil life create pathways between aggregates. They move through soil and leave varying amounts of slime trails from their life processes.
- Bacteria produce lots of good slimes as they do their underground work, including helping plants access nitrogen, helping with decomposition, and many other known and yet-to-be-discovered microbial processes.
- The gluing of soil particles together into aggregates, and the movement of life through soil, helps maintain pores and channels in the soil for air and water to enter and move through it, just like a sponge.

Part Four: Play with Some Slimes

Soil aggregates are more stable and harder to wash away than individual soil particles during rainstorms. Some of these slimes and glues are **hydrophobic**: water will easily slide by them without breaking the sponge apart. Other parts of the sponge—in particular the mineral particles themselves—are **hydrophilic**, meaning that water molecules will stick to them and they will help soils retain moisture. It all works together to create healthy soils that accept *and* filter water.

Bring in some fine sand and some biological slimes and glues that participants are familiar with: raw eggs, slugs, decomposing mushrooms in a plastic bag, decomposing carrots or other root vegetables, etc.

› *Can you think of an experiment we could do to see which of these are hydrophobic?* (For example, raw egg will typically hold its own even if water is poured over it.)

› *Can you think of an experiment we could do to see which of these will stick sand together?*

Part Five: Demonstrate How to Collect Samples and Field Data

1. Give teams of participants a trowel and container for samples (bucket or plastic bin).
2. Explain that when they do this on their own, they will choose one or more places where they will collect relatively intact samples from the top 4 inches of soil by cutting out a cube of soil with a trowel (each sample should be about a 4 inch cube—about two trowels' worth). If there is plant material, have them include the plant material in their sample at this point (they will remove it later, but this gives them the option to separate the sample into two parts, to run a test to see how much of the aggregation is due to root hairs, versus biological glues). Have them mark the samples clearly with a location name, and take a photo. Ask them to photograph the location (one photo straight down from chest height, and one at an angle so that the ground surface and the horizon or skyline is visible) and *also fill in the data collection sheet on paper*, as they collect samples.

Part Six: Participants Collect Their Own Samples and Data in the Field

Depending on the amount of time you have available (as well as access to variations in land management surrounding your class location), samples can be collected as homework and brought to class (giving you a wider variety of samples), or can be collected during class time. Examples of interesting places to sample and compare are:

- Playing fields—both lush, grassy areas of the field *and* bare, worn-down areas *and* un-mowed areas at edges
- Mowed lawns *and* un-mowed areas near those lawns
- Edges of roads and parking lots with bare soil *and* with plant cover
- Gardens, tilled versus non-tilled
- Farm fields near each other, bare fields *and* fields using continuous cover crops, tilled fields *and* no-till systems
- Pastures near each other, one with season-long grazing *and* one using rotational grazing
- Stream and river banks—areas where you see erosion, *and* areas where plant cover is continuous to water's edge
- Commercial potting soil
- Construction sites
- Native grasslands
- Forest soils

➡ **Note:** The greater the variety of samples, the more likely you are to observe interesting variations to soil slake test results that may be due to a number of complex biogeophysical factors. For example, the NRCS Soil Health Team notes:

> "*The mineral particles of the thick, dark soils of the Midwest are held together by organic matter that was created decades or centuries ago. This recalcitrant organic matter is resistant to decomposition. If these soils are cultivated, the soil clods will fall apart very fast in a slake test as sand-sized aggregates [not to be confused with actual sand-sized mineral particles]. The water will remain clear after the sand-sized aggregates settle to the bottom of the jar.*"

Part Seven: Perform Soil Slake Tests in a Group Setting and Photograph and/or Videotape the Results

1. Have participants bring their clods of soil back to a central location or classroom, making sure that each sample is clearly labeled. If there is time, soil samples should be dried on a windowsill (or on dashboard of a car) for several days before testing. This increases the reliability of the test.
2. Give participants the materials to create a water immersion test for soil slaking. Have them make a basket of mesh (out of folded ¼" wire mesh or part of an onion bag secured to the jar with a rubber band) that hangs down into the clear jar or cup. The mesh should hang low enough so that the clod can be fully immersed in the water, but high enough that there is still plenty of space below where participants can watch the soil falling and see the water getting cloudy or staying clear.
3. Ask participants to break off a 2" × 2" clod from about two inches below the surface of one of their samples. Immerse one clod from each soil sample in each jar. Have them observe the results, recording their observations on data sheets if you are using them.
4. After several tests have been completed, and participants have had a chance to watch, ask them to predict what will happen in the remaining ones.
5. Have participants take a photograph of their completed soil slake test against a light colored background. Photos can be uploaded to a public map of soil health and watershed function via atlasbiowork.com, and/or labeled and saved for use in a poster session.

Part Eight: Connections

Connect participants' observations back to things they may have observed around them, and to other subjects they may be studying.

› *Based on what you saw today, where else do you think you would find soils that stayed together? Where else do you think you would find soils that fell apart?*

› *Think of an area where you know there is erosion. Describe the erosion. What kinds of strategies would you try to reduce erosion?*

› *Think of an area where the landscape is staying intact. Describe the current management. If you were in charge of land management in that area, what would you do to keep the soil structure intact and prevent erosion?*

Soil Structure versus Soil Texture

If your group has already been studying soil texture and the soil textural triangle, this is a great place to discuss the difference between **soil structure** and **soil texture**.

Soil texture is determined by soil particle size, the result of both biological and geophysical forces breaking down rocks over long periods of time. **Soil structure** (closely related to—and sometimes known as—**soil health** or **soil function**) is created primarily by biological influences.

Soil texture (relative percentage of sand, silt, and clay) will influence a soil's tendency to erosion but is not a substitute for soil structure in *managing* erosion. Although clay soils hold together through electrochemical bonds, they still need biology to create air space for water infiltration and plant growth. Increased biological activity and buildup of organic matter can prevent erosion and increase water retention in very sandy soils to hold water at the root zone for plant growth. People have little, if any, influence over soil texture, whereas people can have a large influence over soil structure by using land management that increases biological activity and aggregate formation. The **soil health principles** can be used to guide land managers' decision-making to improve soil structure.

Soil chemistry will also influence soil's capacity to stay intact in the presence of water. Disproportionate amounts of sodium in soils will interact with water in such a way as to create a highly unstable soil structure, prone to erosion.

Aerobic and anaerobic aspects of soil structure and their benefits

The porosity of healthy soil structure, created by biology, involves a lot of pore spaces and pathways. These spaces allow room for roots to grow, and allow air and water to reach plant roots and other **aerobic** soil life. This biologically mediated increase in air and water flows can be especially important in high-clay soils where electrochemical bonds will tend to hold particles tightly together.

Small mineral particles that are bound tightly together can create sealed chambers called **anaerobic microsites**, where more stable forms of soil carbon can acculumulate. Some **anaerobic** organisms can survive in these sites, and the carbon from dead organisms can also remain in them without **oxidating** (turning back to CO_2).

In wetland areas, organic matter can also collect into larger **anaerobic layers**. These anaerobic microsites and layers can store carbon, helping to regulate atmospheric CO_2 and ocean acidification. Over time, this soil carbon may collect into longer-term **carbon sinks** in the form of peat and fossil fuels.

Of course the continual creation of life made possible by the aerobic and hydrologic aspects of soil structure *also* helps to regulate atmospheric CO_2 and ocean acidification (and yes, over time, creates fossil fuels)—because life is carbon on Earth, in a myriad of forms.

Discussion Questions

› *We have just been studying soil structure, and we have also studied soil texture. What is the difference between soil structure and soil texture?*

Remind participants who have studied soil texture that clay particles can stick together via electrochemical bonds in addition to—or instead of—the biochemical and biophysical bonds that create the aggregates of healthy soil structure.

› *If you had pure clay soils, would that substitute for biologically created soil aggregate structure in agricultural land management strategies to prevent erosion and silting? Why or why not? What would happen if you had no aggregate structure in pure clay soils?*

› *How do the pore spaces between aggregates benefit plant growth?*

Remind participants that sandy soils often have trouble retaining water at the root zone.

› *Sandy soils will absorb water very easily, but sometimes can't retain water and so remain prone to drought. Would increasing biological activity and resulting organic matter help that situation or make it worse? Explain your thinking.*

› *How do you think root hairs, biological slimes and glues, and fungal hyphae would impact the capacity of sand to retain water at the root zone?*

› *How might we test that?*

Point out that very sandy soils will fall apart but won't cloud the water in a slake test.

› *Why do you think sand doesn't cloud the water?*

Explain biology's role in creating anaerobic microsites and anaerobic layers in peat bogs and wetlands. Explain **oxidation** of soil carbon and its relationship to atmospheric carbon levels.

› *Remembering that all soil life has carbon in it, what do you think the relationship of these anaerobic areas might be to oxidation? How about the carbon cycle as a whole?*

› *What benefit might anaerobic microsites provide?*

› *What benefit might the anaerobic layers in peat bogs and wetlands provide?*

Explain that well-aggregated soils with high organic matter and a porous sponge-like quality also filter water.

› *What difference does water filtration make, and to whom?*

› *Can you design an experiment to test the filtration capacity of soils and compare it to the slake test? What sorts of things could you try using soils to filter that would be relevant to current environmental concerns?*

Point out that sodic soils will fall apart easily, not necessarily because of a lack of biology.

› *Sodic soils (soils with disproportionately high amounts of sodium in their cation exchange complex) will typically fall apart quickly in a soil slake test. What do you think might be happening in that case?*

Assessment Options

- Ask participants to develop a plan, based on what they learned, and building on the soil health principles, to reduce erosion in an area that is familiar to them.
- Invite in some local farmers and/or local policy makers and have participants do a demonstration and talk.
- Ask participants to create a video demonstrating the soil slake test, in which they show results from various management strategies, and explain biological factors in soil aggregation and erosion.

Additional Projects

1. Have participants design rainfall simulators out of soda bottles or other materials, and test intact soil samples from the same areas where they collected slake test samples.
2. Have participants design wind simulators, and test dried soil samples from same areas.
3. Compare data from the three experiments.

Moving Forward

Go around in a circle:

› *What did you learn and how do you feel about it?*

› *What new questions do you have?*

Collect these questions, and use them to build additional investigations, and/or submit them to our curriculum-building project at landlisteners@gmail.com.

handout

FIELD DATA SHEET

Observation Hoop and Slake Test Sample Collection

Your name: ____

Date of sample and observations: ______________________________

Name this location in a way that you will remember it: ________________

Address of location: ______________________________________

Name and phone/email of contact person for location: _______________

____

GPS location: (with at least 5 numbers after the decimal, e.g., 45.62020, -117.77186)

____

GPS accuracy: (e.g., "within 16 meters")______________________________

SURFACE OBSERVATIONS

1. Place the 94" hoop on the ground, right next to the place where you will take your sample. The surface should look similar to where you plan to take the sample. Make sure that the ends of the hoop (or wire) are touching to form a complete circle, and that the circle is round, not oval.

2. Write a sign saying the date, and the name you have chosen for this location ("CEDA-1").

3. Place the sign on one side of it, and take two photographs of the hoop:
   a. One photograph looking straight down at the hoop, that includes the sign.
   b. Step back a few paces and take a photograph of the hoop at an angle that includes the hoop, the sign, and the horizon. Get a little sky in the frame, but not too much.

4. Using your hand, calculate the percentage of bare soil that you can see within the hoop. (The following percentages correspond to an average adult hand. You can adjust accordingly if small children are doing the measuring.)
   a. Whole hand with fingers at maximum spread = 6%
   b. Whole hand with fingers not spread = 4%
   c. Bottom of fist = 1%
   d. Thumbprint = ⅓%

5. Add up the percentages of bare soil, and record the result. ____________________
   Optional: In perennial pastures, record percentages of other definable covers (using subtraction if convenient), such as litter, moss or algae, rock, or plant base.

6. How many centimeters (depth) of dead and decaying plant material ("litter") do you see on the soil surface?

7. Does the soil surface appear to be sealed off from rain, or can see you open pores?

8. How many different grass species? (If you know names of species, write them down too. Otherwise just count the number of different types.)

9. How many different broad-leafed plants ("forbs")?

10. How many shrubs or shrub-like plants?

11. How many different tree saplings?

12. Are there mounded clumps of grass that seem to be part alive and part dead? Yes / No

13. Which of the following do you see: moss, mold, lichen, mushrooms?

14. How tall are the tallest plants on top of your sample?

15. What insects, or signs of insect activity (worm castings, anthills, etc.) do you see?

16. What else do you notice about the soil surface?

LAND MANAGEMENT

17. Are grazing animals integrated into the management here? What type(s) of animals? What stock density? How long are they allowed to graze and how often?

18. How often is tillage used here?

19. Are any inputs are being added? (nitrogen, compost, manure?) What brands, what amounts, and how often?

20. Are any biocides are being used? (pesticides, herbicides, fungicides, insecticides, deworming of livestock?) What brands, what amounts, and how often?

21. Do you see any signs of erosion within 10 feet of where you are taking the sample? What do you see?

22. Do you think this soil will hold together in water or fall apart? What makes you think this?

23. Optional: Assess the soil texture using the soil texture ribbon test and soil texture triangle. What kind of soil would you say this is? How does this influence your guess about whether you think this soil sample will hold together in water?

24. Check the location on a soil map. What general type of soil texture is expected to be found here?

WORKSHEET

Soil Slake Test: Observations and Discussion

Please answer the following questions on a separate piece of paper.

Observations
Before immersing the soil in water:

1. Where did you get each sample from? Make sure you have labeled them.
2. What is the structure of each soil like? Is it light and porous, or heavy and dense? If your sample is large enough, keep some on the side. If not, take a picture of it, and label it.
3. What do you think is going to happen to each sample when you put it into the water?

Immerse each sample in water, and wait a couple of minutes.

4. What did you observe? What happened?
5. Which soils stayed together better? Which ones fell apart?
6. Which water is the clearest after the test? Which are cloudiest?
7. Have you ever seen anything like this happen in the world? Where? What places or events does each jar remind you of?
8. What surprised you about the results?
9. What questions do you have?

Thinking about the results in terms of the larger landscape

10. Why do you think that happened? What do you think makes the difference between the different samples?
11. Can you correlate anything about how well each soil sample stayed together with how the land was being managed? (e.g. tillage versus undisturbed/no-till, living roots in ground versus none, plants growing on top versus bare.)
12. Who made the biological glues and threads that are holding the mineral particles together? What kingdoms of life do you think were involved? What signs would you see of that life if you went back and looked at the land? Would you need a microscope?

13. If biological factors are holding things together better in soils that have more life in them, where else do you think you might find soils that stayed together in water?

14. Where else do you think you might find soils that fall apart?

15. Do you think these biological glues would prevent wind erosion as well? How could you test that?

Thinking about the implications of the results

16. Why are we doing this test? What difference does it make whether soil stays together or not? What difference does it make if the water gets cloudy? What issues does this relate to in farming, economics, human health, and environmental health?

17. What else do you think is important about aggregate structure? (Think back on the Flour vs. Bread test, if you have already done it.) What else would soils with good aggregate structure do in a landscape besides holding soil together in water?

18. Who benefits when soils stay together? In what ways?

19. Sometimes it is hard to avoid disturbing soil structure, such as when growing root vegetables, or on a construction site. What could you do to maintain more soil glues in situations where soils have to be disturbed? How would you create biologically active soils?

Soil texture versus soil structure

20. Soils with high clay content will often stick together through electrochemical bonds. Is this a substitute for biological glues in preventing erosion on farmland? Why or why not? What would clay soils be like without biological aggregation?

21. How much control do we have over soil texture versus soil structure?

A Walk in the Rain: Observing Soil and Water Interactions

Participants observe and document erosion, runoff, ponding, sealing, and infiltration in a variety of places during and after an actual rainstorm.

EDUCATIONAL STANDARDS

Next Generation Science Standards

Performance Expectations
HS-ESS2-5. Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.
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.

Science and Engineering Practices
Asking Questions and Defining Problems.
Planning and Carrying Out Investigations.

Disciplinary Core Ideas
LS2.C. Ecosystem Dynamics, Functioning, and Resilience.
ESS2.A. Earth Materials and Systems.
ESS2.C. The Roles of Water in Earth's Surface Processes.
ESS2.E. Biogeology.
ESS3.B. Natural Hazards.
ESS3.C. Human Impacts on Earth Systems.

Crosscutting Concepts
Scale Proportion and Quantity.
Systems and Systems Models.
Energy and Matter: Flows, Cycles, and Conservation.
Stability and Change.

Common Core State Standards

RST 9-10.7. Translate information expressed visually or mathematically (e.g., in an equation) into words.

National Council for Agricultural Education Standards

CRP.05. Consider the environmental, social, and economic impacts of decisions.
NRS.02.02.01.c. Evaluate how the availability of natural resources can be improved through changes to human activity.
ESS.03.02. Apply soil science and hydrology principles to environmental service systems.

INVESTIGATION

A Walk in the Rain: Observing Soil and Water Interactions

Time Required: 50–120 minutes total. 15–25 minutes outdoors.

Setting: Participants will spend part of this activity in teams outdoors documenting rain hitting a variety of natural and human-made surfaces—in most cases you can find quite a variety of phenomena even in an urban setting. Make sure you choose a setting where there is at least some chance to see rain hitting plants (even potted plants will do in a pinch), loose uncovered soil or sand, and impermeable surfaces, such as pavement. *See note below for how to do this exercise even if it's not raining.*

Summary: Most people have pleasant sensory memories of playing in puddles and watching and directing the flow of water, sticks, and soil during and after rainstorms as children. The observations we made as children form the basis of our understanding of the physics of water and biology's role in protecting living landscapes against the force of water. However, these potent early observations often remain only partly conscious, and we don't necessarily have language to describe what we are seeing, or a sense of agency to put these observations into practice as we begin to take on land management as adults. In this exercise, participants get to re-experience some of the fun they had as children while also forming a foundation of observations they can connect to current events and responsible land stewardship.

Part One happens during and/or immediately after an actual rainstorm. Participants put on some basic rain gear and head out in teams of three or four to find, observe, photograph, and videotape erosion, runoff, ponding, soil sealing, and infiltration as it is happening, then write about and discuss what they observed.

In Part Two, participants go back to the same places 24 to 48 hours later to document where water is still standing, and where contact with water has changed the landscape in subtle or not-so-subtle ways.

Part Three serves as an assessment exercise: Participants use the footage they shot during rainstorms to create short videos or posters in which they show and name the effects of water on differently managed landscapes. This footage should be saved as it can form the basis for a longer project, later in the program.

- **Note: What to do if it's not raining…** If, because of drought, schedule, or other reasons, you don't get a chance to do this exercise in an actual rainstorm, you can photograph and film simulated rainfall outdoors in a number of settings by pouring water into containers that have holes punched in the bottom (plastic milk jugs with the tops cut open work well). You can also ask participants to remember what they've observed in the past when they explored puddles, streams, and the formation of gullies. You can also assign (and/or help) participants to collect photos and video footage from a variety of online sources to complete the activity.

Goals

Participants will:

- Be able to recognize, name, and explain the following soil and water interactions: interception of rain by soil cover, water erosion, infiltration, ponding, sealing, and runoff.
- Have a visual sense of the physics of water movement during rainstorms, and the impact of rain on soil particles in a variety of management settings.
- Collect photos and video footage of soil and water interactions in their own surroundings that they can draw on for several different projects.
- Identify high-functioning and low-functioning areas in the surrounding landscape as they begin to consider how they might improve local land function.
- Keep asking:
  - *"How do soil and water interact under different conditions and management?"*
  - *"What can I do to make the land and watershed around me more functional?"*

Assessment

1. Participants will collect and correctly label photos and video footage of various soil and water interactions.
2. Participants will create a video, poster, or slide show that demonstrates their ability to correctly identify and explain the following: interception of rain by plants, infiltration, water erosion, ponding, soil sealing, and runoff.

Materials

☐ Raincoats and/or a box of large contractor bags for participants who don't have rain gear.
☐ Scissors for making rain gear.
☐ Mobile devices or cameras that can take photos and videos in the rain—if working in teams, one for each team.
☐ (Optional) Umbrellas if your cameras need protection from the rain—other participants can help hold them.
☐ Gallon-size clear plastic bags that will cover instructions.
☐ A whistle to signal participants that it is time to return to a central gathering place.
☐ Instructions: What to Look For During Your Walk in the Rain.
☐ Worksheet: What Did You Notice During Your Walk in the Rain?
☐ Instructions: Things to Notice After the Rain.
☐ Worksheet: Defining Soil and Water Interactions.

Additional materials if you need to simulate rainfall

For each team:

- ☐ Access to plenty of water (a hose or outdoor spigot is great) and/or some way to transport water (wheelbarrows, garden wagon or carts, etc.).
- ☐ 2 or 3 one-gallon plastic water jugs.
- ☐ 1 half-gallon plastic milk jug with about 10 holes poked in the flat bottom. The pouring spouts can be cut off to make a wider opening to pour water in—leave the handles if you like so you can string them all together to carry and store them. (It's probably safest for the facilitator to prepare these ahead of time at home, using a heated metal skewer to make the "rain" holes, and sharp snippers or heavy-duty scissors for the tops.)

Things you will want to know, or review, before leading this activity

Participants may observe a number of possible phenomena. I'd suggest allowing participants to observe these phenomena before the facilitator describes or labels them. Once people have labels for phenomena, they may not observe them as closely.

1. **Interception of rain by plants and other soil cover:** Plants, plant litter, woodchips, and bark mulch can serve a protective function against the compacting effect of raindrops on delicate soil surface pores. Participants will observe water collecting on leaves of plants (or the surface of litter or mulch) and running/dripping down slowly and gently onto the soil surface.
2. **Infiltration into soil:** Rain will disappear quickly into healthy, well-aggregated soils, as long as there is adequate cover to soften the force of the rain, and as long as the soil pore space is not **saturated**—completely filled with water. (Heavy rain for multiple days can **saturate** even a fairly healthy soil.)
3. **Water accumulation: runoff, ponding, and dams:** Water will fail to soak in and accumulate on the surface of soils any time the rate of rainfall exceeds the rate of **infiltration**. Lack of water infiltration and resulting runoff and ponding can be due to a number of (often interconnected) issues, such as poor soil health, poor aggregate structure, compaction, high levels of clay, presence of ice or snow blocking pores, and surface crusting and sealing.

   Accumulation of water can take two forms: **ponding** (pools of standing water) or **runoff** (moving water).

   Pools can form in depressions in a landscape, or behind **debris and dams** in a sloping landscape or stream, when water accumulates faster than the rate of infiltration and evaporation. This accumulation is called **ponding** (or **flooding,** on a larger scale). Ponding and flooding vary in duration. In some cases, water can remain for hours, days, or weeks after a rainstorm. A well-constructed beaver dam can hold water for years.

   The presence of ponding often indicates poor soil health in the area itself, and/or an overload of water due to **runoff** from an unhealthy soil (or impermeable surface) farther uphill.

On sloping soils without adequate capacity to absorb the water, participants may see flows of excess water moving downhill, which is called **runoff**. The water may move in a channel or stream, or in a more general flow across the surface. If the water moves outside of a channel (stream), this is called a **non-point source** of runoff. If a non-point source of runoff carries pollutants or contaminants (for example from agricultural inputs, manure, etc.), this is called **non-point source pollution.** This pollution may or may not be visible to observers, but it can be tested for, especially at drainage points. The area the water is draining from is called a **drainage basin**.

If runoff happens in a permeable or semi-permeable channel and the soil is lacking biological binders, **erosion** may result.

4. **Erosion:** In soils without adequate biological binding of mineral particles (roots, fungal hyphae, and hydrophobic slimes and glues), participants will observe the movement of soil with the flow of water. This movement can be subtle, such as the light movement of a thin layer of mineral particles as rain splashes on a driveway, or it can be extreme, in the case of a deep **gully** that opens up in a field, or a streambank caving in as water rushes past. The five types of erosion are:
    a. Splash erosion
    b. Sheet erosion
    c. Rill erosion
    d. Gully erosion
    e. Streambank erosion
5. **Impermeable surfaces:** Rocks, roofs, pavement, aqueducts, and many other surfaces are impermeable to rain. Impermeable surfaces will direct water somewhere other than the surface it falls on—increasing rain's impact in the areas where it is directed. Participants should note areas that are impermeable, where the water from those impermeable surfaces is going, and how it is impacting them.
6. **Permeable, non-soil areas and structures:** Particularly in urban settings, participants may find such things as permeable pavement, drains, sewer openings, bark mulch, and other places where water can permeate. A question to ask about these places is: *How soon does that water return to natural soil systems, if at all? Where does it go?*

After the rain, participants may also observe:

7. **Crusting and sealing:** Three types of crusts and seals can happen,[1] some from rain, and others which may influence ponding and runoff.

1 Soil Tillage in Africa, Needs and Challenges, FAO Soils Bulletin 69, Chapter Five http://www.fao.org/docrep/t1696e/t1696e06.htm

Surface sealing is defined as the orientation and packing of dispersed soil particles that have disintegrated from unstable soil aggregates due to the impact of raindrops on poorly aggregated soils. By definition, surface seals are formed at the very surface of the soil, rendering it relatively impermeable to water due to small soil particles that are loosened from lack of aggregate stability, flow through cracks and pores within the soil, and fill the soil pores to the point that it seals off. Any further rainfall will not be allowed to penetrate that seal, causing ponding and further sealing. This is from aggregation breakdown, slaking, and dispersion in situ.

A **structural crust** is defined as a surface layer of the soil, ranging in thickness from a few millimeters to a few centimeters, that is much more compact than the material beneath. Structural crusts are formed by physical forces as a result of trampling by livestock or through traffic by agricultural machinery and other vehicles. The import of external materials is not involved in the formation of the crust. They form from re-organization of existing particles, with little displacement of fragments and with sorting and sedimentation.

Depositional crusts form when soil particles suspended in water are deposited on the soil surface as the water infiltrates or evaporates. Externally derived materials are always involved in the construction of depositional crusts. This results from fragment and particle displacement during the ponding phase.

Activity One: A Walk in the Rain

Engaging Questions:

› *How many of you like to watch rain, or even walk in the rain? What do you like about it?*

› *How many of you have ever played in a stream or a puddle during or after a rainstorm? What did you do, what did you notice, and what was fun about it? What else?*

› *Have you ever seen flooding? What happened to the landscape? What else?*

› *If we had someone here who knew everything about what happens when rain hits the earth, what would you ask them?*

› *If there were one thing you could magically know—or that you could successfully research or discover—about flooding, erosion, or runoff what would it be?*

Introduce the Activity
Tell participants:
"Usually when people walk in the rain they are focused on one thing: to get back indoors as quickly as possible. Today we are going to put on some rain gear, and take a walk in the rain and stay out there for about 20 minutes and have some fun. We will make ponchos for those who don't have rain gear. **Your job is to try to find how many different things rainwater can do when it hits the ground.** This is an opportunity to catch the rain in the act, so we can study it later, **so you are going to document what you see by taking photos and videos.**

We will divide into teams. One person will take photos, one will take video, and the third will be the scout, looking for interesting things.

➡ **Note:** If you are using cameras that need some protection and are using umbrellas, you can divide into teams of four and have one person use the umbrella, or let the person taking photos also do the videotaping.

Try to make your footage detailed, because we can look back at these images as we are learning what these different phenomena are called, and how water and soil interact under different conditions. We will go back to some of the same spots after it stops raining, and we will use the images you take today to compare what is happening today with what happens after it stops raining . . . or if it keeps raining for even longer.

While you are looking at what is happening outside, be thinking about how this connects to current issues with water. Over the next few days or weeks, you will develop some of your own ideas about how you might manage the landscape around here to prevent flooding, drought, erosion, and runoff. We will use these same images as a basis of a video that will teach people in our community how their own land management can positively or negatively affect what happens to rainwater. An image is worth a thousand words, and with water, a moving image is awesome. But in some cases still photos can be really useful, so **make sure that for each thing you find, you get some still photos and some video.** If you have a way of recording slow motion, you might also do some of the footage in slow motion."

Give participants handouts.
Hand out one copy of the "What to Look For During Your Walk in the Rain" instructions and the "What Did You Notice During Your Walk in the Rain?" worksheet inside plastic bags, for each team.

Tell participants:
"When you come back in, you'll be answering some questions. I'm giving each team one copy that you can take outside. Please look at the questions before you go out. You'll be able to look back over your photos and videos as you answer the questions on the worksheet, but you'll want to observe carefully while you are out there as well. You might want to take some brief notes just to remind yourself of where you saw things, but don't try to fill it all out in the rain."

Ask participants to take turns reading the directions out loud (for those who process best by hearing). Then check for questions:

› *"I will be out there with you to help out. Do you have any questions before we get our rain gear on?"*

Show how to make rain ponchos, and put on rain gear.
If participants have rain gear, give them a few minutes to put it on. If they don't, show them how they can cut the corners off of a contractor's bag to make armholes, and then cut out a neck-hole between the two armholes, to make a very chic rain poncho.

Head outside to a central gathering place and give instructions for outdoors.
Let participants know:

- The boundaries of the area where you want them to collect observations (how far can they go?).
- How much time they have (15 minutes is usually plenty).
- What time you expect them to come back (e.g., "1:15 p.m.").
- Where you want them to meet you when they are done.
- What signal you will give them when they have five minutes left (a single whistle blow).
- What signal you will give them when they are supposed to return.

➡ **Note:** As facilitator, you might want to take a group photo of participants outdoors in the rain at some point—as well as some shots of participants working. These can be fun to include in presentations.

Head back indoors and fill out worksheets.
After returning indoors, ask participants to stay in their teams and fill in the "What Did You Notice During Your Walk in the Rain?" worksheet questions.

Discussion: Functional areas and non-functional areas.
This discussion will give participants a chance to connect their observations to the Flour vs. Bread activity, and to start thinking about landscape function as a whole, and its impact on infrastructure, society, and public health.

› *Based on what you already know about healthy soil structure (the "soil carbon sponge") and its role in absorbing and filtering water, where did you notice that the soil structure seemed to be functioning well? What makes you think that? What evidence did you see?*

› *Where did you notice potential problems? Why do you think it's a problem? What evidence did you see? What kinds of issues do you think these problem areas might be contributing to?*

Ask participants to share their most interesting observations. Let them know that some of these functional and non-functional areas might be places they will want to focus on if they do a project involving a management plan.

Labeling observations.
As participants share their observations verbally, start giving names and descriptions to the various phenomena and concepts listed below. If the group is small enough to gather around a small screen, ask participants who think they have clear images or videos of the following phenomena to show their images to the group. Let them know they will do a more formal homework assignment to define these vocabulary words and match them to their images before the next meeting.

- Infiltration
- Interception of rain by plants, plant litter, and mulch
- Dam formation: by beavers, humans, or organic matter buildup
- Flooding upstream of dams
- Downstream flooding when dams give way
- Permeable surface
- Impermeable surface
- Ponding
- Erosion
    - Splash erosion

    - Sheet erosion
    - Rill erosion
    - Gully erosion
    - Streambank erosion
- Runoff
- Point source pollution
- Non-point source pollution
- Surface sealing
- Depositional crust
- Structural crust
- Litter movement
- Pedestals and terracetts

Assignment: Defining terms and matching with examples.
Ask participants to research and write brief descriptions of each of the above phenomena (either for homework or as an in-class assignment). See the worksheet "Defining Soil and Water Interactions." While they are doing that research, ask them to start matching these concepts to their own photos and videos, and to see how many things on the list they can give a clear example of using the video and photos they collected on the walk in the rain. It is unlikely they will have noticed sealing and crusting during the rainstorm, so ask them to look online for a photo of a sealed soil surface, and let them know they will likely find actual examples of it outside, after the rain (see activity below.)

Moving forward.
Circle Questions
Ask all participants to take turns answering the following questions (or if time is short, ask them to write answers on a sticky note and put them on the board as they leave):

› *What new questions do you have, based on what you learned today?*

Keep track of the new questions, and use some of them to begin the next activity.

Activity Two: After the Rain

If possible, have participants return to the same sites they observed 24–48 hours later, after the rain ceases, and record anything they notice. In particular, you can ask them to look for:

- Signs of surface sealing, which may not have been easily visible during the rainstorm.
- Results of erosion, after water has receded.
- Any remaining ponding—have them note how many hours standing water remains after the rain ends.

- Evidence of new dam formation as branches and leaves clog drains, gutters, streams, etc.
- Evidence that dams have burst (former beaver ponds that gave way, etc.).

Have them document these with photo and video.

Moving Forward
Circle Questions
Ask all participants to take turns answering the following questions (or if time is short, ask them to write answers on a sticky note and put them on the board as they leave):

› *What did you learn and how do you feel about it?*

› *What new questions do you have?*

Keep track of the new questions, and use some of them to begin the next activity.

Activity Three: Create Presentations for Assessment

Ask participants/teams to create a short video, slide show, or poster that demonstrates that they can properly identify and define the above terms, using the footage they collected and the research they did. At this point they are welcome to use each other's media, their own drawings or other creative ways of showing the concepts, as well as additional (copyright-free) media they find online.

Remind them that this work can help form the basis for their project, later in the program, when they will complete a longer video or other project that clearly demonstrates their understanding of the following:

1. Connections between soil biology, soil aggregate structure, pore space, and infiltration rates.
2. Connections between bulk density and pore space.
3. The impact of soil aggregate structure on runoff and ponding.
4. The impact of soil biology on water erosion.
5. How soil cover maintains soil surface permeability by protecting against the compacting and soil sealing effects of rain.

Make sure they are working in teams that are small enough that you can assess their knowledge of the terms.

Moving Forward
Circle Questions
Ask all participants to take turns answering the following questions (or if time is short, ask them to write answers on a sticky note and put them on the board as they leave):

- *What did you learn and how do you feel about it?*
- *What new questions do you have?*

Keep track of the new questions, and use some of them to begin the next activity.

INSTRUCTIONS

What to Look For During Your Walk in the Rain

Please notice the following as you go from place to place (you'll be writing your answers down when you go back inside):

1. Where is rain disappearing quickly into the ground? What are the characteristics of these places?
2. Where is it forming puddles? What are the characteristics of these places?
3. Where is soil or sand moving or eroding? What are the characteristics of these places?
4. Where is it forming streams? What are the characteristics of these places?
5. Where do those streams seem to originate from, and where does it look like they are heading?
6. What natural and human-made surfaces are catching or deflecting the raindrops and what happens to the water after it hits them? Does it move more slowly or more quickly? Where does it go?
7. How soon does water that is falling on human-made surfaces return to natural soil systems, if at all? Where does it go?
8. Do you see any places where the water might be picking up pollutants as it travels? Where would it be carrying them?
9. Do you see any opportunities to improve things?

Please find, observe, and take a photo and short (5–30) second video of what happens to rain in:

- Several locations where plants are growing (grass, bushes, trees, etc.).
- Several locations where there is bare dirt.
- Water moving past soil in a natural channel of any size (this could be something small forming at the edge of a lawn, or it could be a stream, or a large riverbank).
- Pavement.
- A very sandy place.
- Various other locations and situations: for example, where there is gravel, bark mulch, roof gutters that are draining, storm drains, culverts, etc.
- Any place where you think the water might be picking up pollutants and moving them somewhere else.

Make sure the above places include:

- A few sloping places.
- A few flat places.
- A few places where there is a depression in the ground.

WORKSHEET

What Did You Notice During Your Walk in the Rain?

1. Where did rain disappear quickly into the ground? What else did you notice about these places? What are your ideas about why that was happening?

2. Where did rain form puddles? What else did you notice about these places? What are your ideas about why that was happening?

3. Where was soil or sand moving or eroding? What else did you notice about these places? What are your ideas about why that was happening?

4. Where was water forming streams? What else did you notice about these places? What are your ideas about why that was happening?

5. Where did those streams seem to originate from, and where did they seem to be heading?

6. What natural surfaces were catching or deflecting the raindrops and what was happening to the water after it hit them? Did it move more slowly or more quickly? Where did it go?

7. What human-made surfaces were catching or deflecting the raindrops? How soon did the water that was falling on human-made surfaces return to natural soil systems, if at all? Where did it go?

8. Based on what you already know about healthy soil structure and how it absorbs and filters water, which places seemed to be functioning best? Why do you think that? What evidence do you have?

9. Did you see any places where leaves or branches were being carried by the water? Did they end up somewhere where they would form a dam or clog a drain or culvert? What problems might that cause? Might there be any benefits?

10. Did you see any water issues that you think could become problematic or dangerous in a heavy or more continuous rain storm? What were these issues, and what do you think could happen? Where would the issues have their biggest impact? Where else?

11. Did you see any places where water might be picking up pollutants? (Sewage, fertilizers, pesticides, manure, oil, etc.) Where would it go and who or what might it affect downstream?

12. Based on what you know right now, what ideas do you have about how you might improve things? What would you do? What would you hope would happen differently with water flows and infiltration? What effect would you want it to have?

INSTRUCTIONS

Things to Notice after the Rain

1. Review definitions of soil sealing and crusting, then see if you can find and photograph evidence of the following:
    - Surface sealing
    - Depositional crust
    - Structural crust
2. Go back to places where you noticed ponding or water accumulation during the rainstorm. Is it still there? How many hours has it been since it stopped raining? Photograph what you find.

3. What evidence of the following kinds of erosion can you find? Photograph the evidence.
    a. Splash erosion
    b. Sheet erosion
    c. Rill erosion
    d. Gully erosion
    e. Streambank erosion

4. Can you find any new dams (any size, small or large)? Photograph them.

5. Can you find any places where dams burst and changed things? Photograph the evidence.

WORKSHEET

Defining Soil and Water Interactions

1. Please research and write a short definition of each of the terms below in a way that someone else can understand and imagine the phenomenon, and also in a way that will help you identify it in the future.
   - Infiltration
   - Interception of rain by plants, plant litter, and mulch
   - Dam formation: by beavers, humans, or organic matter buildup
   - Flooding upstream of dams
   - Downstream flooding when dams give way
   - Permeable surface
   - Impermeable surface
   - Ponding
   - Erosion
     - Splash erosion
     - Sheet erosion
     - Rill erosion
     - Gully erosion
     - Streambank erosion
   - Runoff
   - Point source pollution
   - Non-point source pollution
   - Surface sealing
   - Depositional crust
   - Structural crust
   - Litter movement
   - Pedestals and terracetts

2. Find photos and videos of as many of these as you can from your own footage.

3. Make a short video, using your own photos and videos as much as possible, that shows examples of as many of these phenomena as you can. Use a voice-over or subtitles to explain to viewers what you are showing, what it is called, and what positive or negative effects it could have, depending on the context or circumstance.

   For example:

   a. In what circumstances is ponding a good thing? When would you not want ponding? What positive effects could it have, and what negative effects?

   b. In what circumstances is flooding upstream of dams a good thing? When would you not want it to happen?

The Fenceline Photo:
Seeing and Understanding Landscape Function

Photo Credit: Kroon Family

Participants use a fenceline photo to think about functional and structural differences (in water, carbon, and nutrient cycling) between a healthy grassland and a degraded grassland.

EDUCATIONAL STANDARDS

Next Generation Science Standards

Performance Expectations:
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-LS2-6. Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.
HS-LS4-5. Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.

Science and Engineering Practices:
Analyzing and Interpreting Data.
Engaging in Argument from Evidence.
Obtaining, Evaluating, and Communicating Information.
Constructing Explanations and Designing Solutions.
Asking Questions and Defining Problems.

Disciplinary Core Ideas:
LS1.A. Structure and Function.
LS1.C. Organization of Matter and Energy Flow in Organisms.
LS2.A. Interdependent Relationships in Ecosystems.
LS2.B. Cycles of Matter and Energy Transfer in Ecosystems; Ecosystem Dynamics, Functioning, and Resilience.
LS4.C. Adaptation.
LS4.D. Biodiversity and Humans.

Crosscutting Concepts:
Patterns.
Cause and Effect.
Systems and System Models.
Energy and Matter: Flows, Cycles, and Conservation.
Structure and Function.
Stability and Change.

Common Core State Standards

SL 9-10 and 11-12.1. Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade-appropriate topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.
SL 9-10 and 11-12.4. Present information, findings, and supporting evidence conveying a clear and distinct perspective, such that listeners can follow the line of reasoning, alternative or opposing perspectives are addressed, and the organization, development, substance, and style are appropriate to purpose, audience, and a range of formal and informal tasks.
RST 9-10.7. Translate information expressed visually or mathematically (e.g., in an equation) into words.
RST 11-12.9. Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

National Council for Agricultural Education Standards

CS.06.01. Examine and explain foundational cycles and systems of AFNR.
CRP.05. Consider the environmental, social, and economic impacts of decisions.
CRP.04.03. Model active listening strategies when interacting with others in formal and informal settings.
NRS.01.06. Apply ecological concepts and principles to living organisms in natural resource systems.
ESS.03.02. Apply soil science and hydrology principles to environmental service systems.
ESS.03.05. Apply ecology principles to environmental service systems.
ESS.05.02.04.c. Evaluate a habitat to determine its ecological quality and if it is threatened.

INVESTIGATION

The Fenceline Photo: Seeing and Understanding Landscape Function

Time Required: 45 minutes to 3 hours.

Summary: This photograph of two neighboring but differently managed landscapes—one in the process of desertification, and the other in the process of grassland regeneration—offers a wonderful entry point for a discussion of whole systems landscape function and the impact of management on natural systems. This first investigation starts with learning to see flows of water, carbon, nutrients, and heat through the matrix of soil and plants. (In the second investigation, participants will engage in a "forensic" group discussion to figure out what happened in this landscape, and why.)

Participants make as many observations as they can about the photo, then answer a series of questions that get them to think about the structure and function of the land on either side of the fence. For example:

› *If it rained, on which side do you think water would evaporate more quickly? Why?*

› *Which side do you think is accumulating more carbon in the soil over time? Why?*

› *If you buried a pair of cotton underpants in the soil on each side, which do you think would biodegrade faster? Why?*

In the process, participants learn to notice and interpret signs and symptoms of change over time in a grassland ecosystem. They finish this investigation by guessing what happened to make the landscape so different on each side of the fence, as preparation for the next investigation.

The purpose of this exercise is:

- To heighten visual observational skills of whole-systems landscape function
- To provide a context for understanding feedback loops and relationships between the carbon, water, and nutrient cycles in actual landscapes
- To develop skills in evaluating human impact on natural systems
- To engage students in a discussion in which they can share observations and ideas, and develop individual and group hypotheses

Goals

Participants will be able to:

- Compare details of a degraded grassland with a regenerated grassland.
- Begin to see flows of matter and energy—such as water, carbon, nutrients, sunlight, and heat—in two different landscapes based on visual cues.

- Use visual cues to roughly compare the structure and function of two neighboring landscapes in terms of:
  - carrying capacity
  - soil compaction/density
  - soil temperature
  - ambient temperature
  - nutrient cycling
  - carbon gain or loss
  - moisture-holding capacity of soils
  - evapo-transpiration
  - biological diversity
  - socioeconomic value
- Use these comparisons to begin to evaluate the human impact of different land management strategies on a natural system.

Materials

- ☐ Projector for large class, ***or*** large print-out of the Karoo fenceline photo image, ***or*** a computer that everyone can gather around to look at the image (for small class).
- ☐ PowerPoint slide of the Karoo fenceline photo (available at www.soilcarboncoalition.org/learn).
- ☐ A bell or other sound to begin and end the observation period.

Activity

Observation
Quietly observing all the details of a landscape before attempting to make meaning out of one's observations is a step that is often overlooked when evaluating landscapes or other complex systems. This helps to focus participants' minds, and create a neutral baseline from which the group can build a fresh perspective. Without this step, people will tend to notice only those things that fit the constructs they already have, and will jump to conclusions about what is happening based on an incomplete set of details. It is also a simple and inviting exercise that all participants can participate in equally, regardless of their previous knowledge base.

Tell the group:

› *When I ring this bell, I'd like you to take one minute of silence to notice everything you can see in the picture: colors, shapes, textures, details. You'll see things you know the names of and things you don't know the names of. After one minute, I'll ring the bell again, and then we'll list off everything we are seeing.*

After one minute, ring the bell and ask:

› *What do you see here? What do you notice? Let's go around the room and each person can say one thing.*

Participants may notice things like: a fence, with barbed wire. On the right there is bare soil with just a few plants. On the left there is a lot of grass. Yellow and white flowers. Trees in the distance. There are some tire tracks in the grass. Hills in the distance, a clear blue sky . . .

Write their answers on the board. If people try to come to conclusions about what they are seeing, direct them back to the task at hand: to simply collect a set of observations.

Keep asking "*What else do you see?*"

Focusing Questions
This next set of questions is intended to get participants thinking about various elements of landscape structure and function. Most people haven't thought much about these things, even though they have experienced them in a multisensory way while walking outdoors, digging, watching rainstorms, etc., and likely we all have some cultural or genetic memory of them from times not that long ago when human survival depended more acutely on our ability to connect visual cues in order to read landscapes and weather.

As you listen to your group discussing these questions, you will get a sense of their current level of understanding, but keep in mind that this may grow considerably as they hear each other thinking out loud during this exercise.

➡ **Note:** It's okay if they don't get everything right. In fact, for most groups, rather than correcting participants as they go along, you will probably engage them more deeply by simply letting them answer all the questions in whatever way they think is correct (allowing them to debate a bit between themselves) and saying nothing more than *"hmmm… interesting!"* yourself.

However, I have included brief answers so that later on, you can return to the points where participants were way off. At that point you can discuss the questions in more detail, and help them to rethink and adjust their working models of how landscapes function.

You can have participants discuss the questions in small groups first, if you have time, and then share in a larger group discussion, but either way is okay. There are several places in the list where similar questions circle back around again—this is on purpose, as the information may start to make more sense when participants hear it again in a different context.

Another good question to add on to some of the more experiential questions is *"What experience do you have that gives you that idea?"* or *"What makes you think that?"* (with a light and interested tone). I have left that off of the list, other than in the first two examples, simply to save space, but keep it in mind as an option to help students make connections.

Ask some or all of the following questions, depending on the age and experience of your group.

Sunlight, Temperature, and Heat

› *Which side do you think would be hotter to stand on? What experience do you have that gives you that idea?*
  The right side would be hotter.

› *If it rained, which side would evaporate faster? Why? What makes you think that?*
  The right side would evaporate much faster primarily because soil temperature is higher.

› *How would that evaporation impact the amount of water getting to the plant roots?*
  A lot less water getting to plant roots.

› *Which side do you think gets more sun?*
  Partly a trick question, but helps to get them oriented—and some may correctly note that the soil on the left is absorbing less heat from the sun, but also creating more with the sun that it gets.

› *What is the sunlight doing on the left side?*
  Lots of photosynthesis—creating more life.

› *What is the sunlight doing on the right side?*
  Lots of heating of soil and evaporation of water, not much photosynthesis.

› *If the air temperature was 90 degrees Fahrenheit, what do you think the soil temperature would be on each side?*
  The soil temperature would likely be higher than 90 degrees on right, and lower than 90 degrees on left.

› *If a whole continent changed to become more like the right side, would you expect that continent to be cooler or warmer than one that looked like the left side? Why?*

Hotter, for a variety of reasons, including that ambient air temperatures would be affected by higher soil temperatures.

› *What places in the world look like the right side? What are typical temperatures and rainfall there?*

› *What about the left side?*

Plant Cover

› *Which side has more plant cover?*

› *In what ways do you think the increased plant cover on the left would impact the soil temperature?*

It would lower the temperature by shading the soil, reflecting more of the incoming solar radiation via the albedo effect, by keeping the soil more moist, and cool the area through transpiration.

› *How would the plant cover affect water infiltration into the soil?*

Plants and plant litter create millions of tiny dams that keep water in place for longer, allowing it to infiltrate, cool the soil so that water doesn't evaporate as quickly, and reduce the compacting effect of raindrops hitting the soil.

› *Which side do you think has more roots in the ground?*

› *How do plant roots affect water infiltration into the soil? Why?*

Plant root exudates and decomposing plants feed a variety of soil microbes and other living things that all help to create soil aggregates with pore spaces between them—so soil is more like a sponge. As roots die off, they also leave open channels in the soil where water can move.

› *Where is there more transpiration happening?*

› *What effect do you think that has on the ambient temperature and local weather?*

It dissipates heat from the surface to the atmosphere via latent heat fluxes creating a cooler ambient temperature. Depending on other factors, it could also help draw rainclouds to the area by creating a cooler and/or lower pressure air column.

Water

› *On which side would rain have an easier time soaking into the soil? Why?*

The left side. Pore spaces in covered soil stay open during rain and have less crusting from rain impact. Plant cover and plant litter creates millions of tiny dams that keep water in place for longer.

› *Which side do you think is holding more moisture in the soil? Why?*

The left side, for a variety of reasons, including less evaporation, more pore space due to root and microbial activity creating aggregates.

› *What might the combined effect of increased soil moisture and increased transpiration have on the creation of water vapor?*

Because the plants have more water to draw from in the soil reservoir, and there are more plants overall, the left side would create more water vapor through transpiration.

› *If the land was sloping, which side would the water run off of more quickly?*

The right side.

› *Which side would be more prone to flooding?*

The right side, because the rain is less likely to soak in to the soil.

› *Which side would be more prone to drought?*

Again, the right side because rain is less likely to soak in to the soil—it is very common for there to be both flooding and drought in the same landscape, and for similar reasons.

› *On which side do you think plants have easier access to water? On which side would there be more competition for water?*

The plants on the left would have easier access to water, even though there are more plants. Likely more competition on the right due to less available water in the soil.

› *Which side do you think gets more rain?*

Partly a trick question to highlight the fact that one can have very different landscapes with the same inputs of rain. However, some may take the question and imagine a larger landscape and correctly point out that the plant life will influence the water cycle in the area—therefore it is possible that the left side does actually get more rain.

Soil Structure and Density

› *On which side do you think the soil is more compacted, has less pore space, and has higher density?*

Likely the right, because it has fewer plants, which means there is less life in the soil to create aggregates and pore space—plant roots, microbes, worms, etc.

› *Which side do you think it would be easier to push a metal probe into? What experience do you have that makes you think that?*

Left.

› *Which side do you think has better aggregate structure? (i.e., which is more like flour, and which is more like bread?) Why?*

The left probably has better aggregate structure because plant life above ground feeds microbial life below ground that, in turn, creates soil aggregates.

› *If you weighed a cup of soil from each side, which do you think would be heavier?*

Probably the right, because there is likely less pore space, so it is more dense and compacted.

› *How do you think it got that way?*

In a desertifying landscape, the lack of plants reduces the food source for underground life, which means that there is no mechanism for the mineral particles—sand, silt, and clay—to form, maintain, or regenerate aggregate structure and other pore spaces from worms, insects, small mammals, etc. The mineral particles become prone to compaction from rain impact, collapse of biologically maintained structures, hoof impact, vehicles, or other forces.

Carbon

› *Which side looks more alive? Why?*

› *Which side do you think has more carbon in the biomass above ground? How about in the soil below ground? Overall?*

The left, both above and below ground.

› *Where is the carbon?*

In the living things, the dead things, and the very dead things: plants, animals, fungi, microorganisms, viruses, and soil organic matter (humus and glomalin). Also in the air, in the form of CO_2. Possibly some calcium carbonate in the soil if this used to be an ocean or lakebed.

› *Which side do you think is accumulating more carbon in the soil over time? Why?*

Probably the left, due to more plants, therefore more root exudates and decomposing plant litter feeding soil life and accumulating organic matter and soil carbon.

› *If most of the land mass in the world looked like the right side, would we have more or less CO_2 in the atmosphere than if it looked like the left side?*

Probably there would be more CO_2 in the atmosphere, because there would be less photosynthesis happening, more oxidation happening, and less carbon in the soil and in living things.

Nutrient Cycling

› *If you buried a pair of cotton underpants on each side, which pair do you think would biodegrade the fastest? Why?*

Likely the pair on the left would biodegrade faster, because a landscape with more plants will generally have more microbes in the soil that can decompose plant-based organic matter, and cotton is made out of plants.

› *If a plant died on the left and on the right, what do you think would happen to each plant, and to the carbon in each plant, and why?*

The plant on the left would likely be decomposed by soil microorganisms, and at least some part of the plant's carbon would become soil carbon, with some of it also being respired by soil organisms. The plant on the right would likely dry up and decompose more slowly; though the mechanisms are not entirely understood, it would include oxidation through a slow "burning" from ultraviolet light and heat, with more of the carbon returning to the atmosphere as CO_2, and less of the plant's carbon going back into the soil. The carbon in the plant on the right would also be at more risk of oxidizing through natural burning from actual fire, due to the dryness of the landscape.

› *The mineral substrate (and content) of the soil is the same on both sides. Do you think one side would grow food with more minerals and other nutrients in it? If so, which side?*
  Likely the left side.

› *How is this possible if the mineral content is the same?*
  Because the additional plants are feeding more microorganisms—such as mycorrhizal fungi and nitrogen fixing bacteria—in the soil, which in turn help the plants gain access to the nutrients.

› *Which side could support more grazing animals on it?*
  The left.

› *On which side do you think the animals would be healthier? Why?*
  Probably on the left: more food/forage, more nutrient density in the forage, more water available within the forage, cooler ambient and soil temperatures and therefore less stress.

Biodiversity

› *Which side do you think has more biodiversity of animals, insects, plants, fungi, and microorganisms?*
  Probably the left side, but not necessarily.

› *How about underground?*
  Hard to say, as there are microbial communities in all sorts of settings.

› *What kinds of animals would prefer to live on which side?*
  Desert animals on the right. Grassland animals on the left.

› *What animals could survive on one side, but not on the other?*

› *If the whole region changed to look like the right, or the left, how would do you think the species living there would respond?*
  Some might adapt, some would move to another region, some would flourish, new species might move in, and some could risk extinction.

› *What sorts of species might be at particular risk?*
  Various answers, but in particular any species that are uniquely adapted to that particular niche.

Socioeconomic

› *Without changing anything, which side do you think is capable of producing more food for human consumption? Why?*

The left is well suited for grazing animals, as long as there is a water source. The soil is almost definitely more fertile and has better water infiltration on the left as well, so crops would likely be easier to grow on the left.

› *If the price of the two pieces of land was the same, which one do you think would be better to invest in, and why? What would you do with it if you were an investor?*

Feedback Loops

› *What sorts of feedback loops do you think are happening in the two landscapes?*
Various, but one example would be lack of water infiltration is making it harder for plants to grow on the right, which in turn makes water infiltration even harder.

› *How are the different parts we have discussed influencing each other?*
Many possible answers, for example: the lack of grass on the right makes it harder for grazing animals to live there, which changes the microbial ecology of the soil due to lack of dung, which then changes the rate of decomposition of organic matter as well as the soil moisture.

What happened?
Ask participants to form pairs or groups of three and answer these questions:

› *What do you think the story is behind this picture?*

› *What do you think happened to make it so different on the two sides of the fence?*

› *What are all the possible explanations for the difference on the two sides?*

Large-Group Discussion
After they have a chance to think in small groups, encourage an open brainstorming session, without critique, of all the possible reasons this landscape might have gotten to look so different on two sides of the fence. Take notes on the board of all the ideas, making it clear that you are just collecting ideas.

Once you have at least eight reasons on the board, allow them to discuss the possible explanations they have come up with, and build on each other's ideas.

Participants may become focused on the tire tracks and the fence—as a sign of human intervention, which is correct: the two sides are both being managed by humans, in different ways. (The tire tracks are on both sides of the fence, if you look carefully.) They may make guesses about animal impact, which is correct; animals have influenced the landscape. They may think that one side has had more fertilizer and other chemical inputs put on it, seeds purposefully planted in it, or that one side has been irrigated.

Ask each small group to reconvene and come up with three questions:

- *What are three "yes" or "no" questions you would most want answers to, in order to make a reasonable guess about what happened here? For example, "Did anyone plant seeds?" "Did they used to look the same?"*

Make a list of the questions.

After this discussion, tell them:

"These are two neighboring sheep ranches in Africa. At first, the whole landscape looked somewhat like the left, then the whole landscape looked like the right side. Now they look like this. The left side is the result of a management practice called holistic decision-making—likely these land managers had a goal of restoring a productive grassland, and getting the water cycle working again."

Wrap-Up

Have participants share the following:

- *What did you learn and how do you feel about it?*
- *What new questions did this leave you with?*

Ask them to write their questions on a sticky note or index card and give them to you. Use these questions to help guide your approach to future investigations.

"The Nation That Destroys Its Soil . . ."
A Letter from the President

Franklin Delano Roosevelt's famous letter about setting up Soil Conservation Districts after the Dust Bowl serves as a focal point for a writing assignment and discussion about the social and economic importance of soil health.

"The Nation That Destroys Its Soil . . ." A Letter from the President

EDUCATIONAL STANDARDS

Next Generation Science Standards

Science and Engineering Practices:
Engaging in Arguments from Evidence.

Disciplinary Core Ideas:
LS2.C. Ecosystem Dynamics, Functioning, and Resilience.
ESS2.A. Earth Materials and Systems.
ESS2.E. Biogeology.
ESS3.C. Human Impacts on Earth Systems.

Crosscutting Concepts:
Structure and Function.
Stability and Change.
Influence of Engineering, Technology, and Science on Society and the Natural World.

Common Core State Standards

SL.9-10.1. Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade-appropriate topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.
RI 9-10.9. Analyze seminal U.S. documents of historical and literary significance.
RST.9-10.2. Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text.
L.9-10.5 and **L.11-12.5.** Demonstrate understanding of figurative language, word relationships, and nuances in word meanings.
RST.11-12.2. Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

National Council for Agricultural Education Standards

AS.01. Analyze historic and current trends impacting the animal systems industry.
NRS.02.03. Analyze how modern perceptions of natural resource management, protection, enhancement, and improvement change and develop over time.
CRP.05. Consider the environmental, social, and economic impacts of decisions.
CRP.04.02. Produce clear, reasoned, and coherent written and visual communication in formal and informal settings.
CRP.01. Act as a responsible and contributing citizen and employee.
CRP.04. Communicate clearly, effectively, and with reason.

INVESTIGATION

"The Nation That Destroys Its Soil . . ." A Letter from the President

Time: 5 minutes reading. 25-minute video or 5–10 minute slide show on the Dust Bowl. 10–20 minutes writing and/or small-group discussion, 15–30 minutes class discussion

Summary: In 1937, Franklin D. Roosevelt (FDR) used the phrase "The Nation that destroys its soil destroys itself." This quote has become a powerful reminder that the lowly soil carbon sponge is literally holding society together and making life possible on land.

FDR wrote this phrase in a letter about soil conservation districts being set up in response to catastrophic flooding and dust storms. This soil conservation effort has had both successes and failures, but today's soil health movement, and the soil health principles, are descendants of the soil conservation movement that began in 1937.

Participants read FDR's letter and watch a video or slide show history of the Dust Bowl. Then—either in writing or in small groups—they share their ideas on FDR's quote, causes of the Dust Bowl, and the societal importance of soil aggregate structure, before engaging in a large-group discussion.

Goals

Participants will be able to:

- Reflect on the essential role of soil aggregates and the soil carbon sponge for humans and other living things.
- Have a visual image of flooding and dust storms in the 1930s.
- Connect flooding and dust storms of the 1930s to the destruction of soil aggregate structure.

Assessment: Completion of worksheet questions, with answers that show participants' understanding and thinking process.

Materials

- ☐ Worksheet: *"The Nation That Destroys Its Soil . . ." A Letter from the President* (Original available online at http://www.presidency.ucsb.edu/ws/?pid=15373.).
- ☐ Pencils.
- ☐ Paper or notebooks.
- ☐ Projector.
- ☐ Slides of Dust Bowl (If you do an image search for "Dust Bowl" and for "flooding during the Dust Bowl" on Google, you will find lots of images.).

☐ Video (optional for class, but I suggest that the facilitator watch it): *The Plow That Broke the Plains*. View online at https://archive.org/details/gov.fdr.352.2a.1 or purchase (with soundtrack) at https://www.amazon.com/Broke-Plains-Gil-Ordonez-Post-Classical-Ensemble/dp/B000L42J5E/

Additional Resources

Books/Articles:

The Worst Hard Time: The Untold Story of Those Who Survived the Great American Dust Bowl by Timothy Egan

Out of the Dust (Newbery Award Winner) poems by Karen Hesse

The Dust Bowl book of photos and primary source materials by Ken Burns (accompanies the video)

Videos:

The Plow That Broke the Plains (26 min) View online at https://archive.org/details/gov.fdr.352.2a.1 or purchase (with soundtrack) at https://www.amazon.com/Broke-Plains-Gil-Ordonez-Post-Classical-Ensemble/dp/B000L42J5E/

The Dust Bowl, multi-part PBS documentary video (and book) by Ken Burns, available on Amazon

Websites:

"30 Facts about the Dust Bowl for Kids" www.american-historama.org/1929-1945-depression-ww2-era/dust-bowl.htm

PBS's Dust Bowl interactive website with photos, interactive videos, and more www.pbs.org/kenburns/dustbowl/

"Dust Storms" Wikipedia page for general and more current information on dust storms en.wikipedia.org/wiki/Dust_storm

Additional Curricula:

www.pbs.org/kenburns/dustbowl/educators/overview/

Activity

Dust Bowl history slide show or video (two options)

Slide show: Bring up a few images of dust storms and flooding from the 1930s on a projector. If you are not planning on showing the video, give a short history of the transition from native prairies to an agricultural system based on tillage.

Video (26 minutes): Watch *The Plow That Broke the Plains.* View online at https://archive.org/details/gov.fdr.352.2a.1

Reading

Ask participants to read the letter from Franklin D. Roosevelt on the worksheet: *"The Nation That Destroys Its Soil . . ." A Letter from the President.*

Reflection (writing assignment and/or small-group processing)

Participants take 15–30 minutes to reflect on the questions attached to the worksheet. You can have them do this in writing, and/or ask them to take turns thinking out loud in small groups (using a timer or a talking stick to take turns). The worksheet questions are:

1. *At the time that this letter was written, what do you think the structure of the soil was like in the areas that were suffering from dust storms and flooding—more like bread or flour? Were the soils well-aggregated or poorly aggregated?*
   Answer: the soil was more like flour—poorly aggregated.

2. *President Roosevelt seems to be implying that humans created this situation, and that humans can improve it. Many of the problematic areas used to be native grasslands (prairies, plains) that were plowed up and turned into farmland. What do you think that did to the structure of the soil, and to the living ecology of the soil, and how do you think it contributed to these events?*
   Answers could include (but are not limited to):
   - Broke apart the soil aggregates
   - Exposed microorganisms to high temperatures that killed them off
   - Compacted the soil and created a plow pan so rain couldn't enter
   - Compacted the soil so oxygen wasn't available to underground life
   - Took living roots out of the soil so there was nothing to feed the mycorrhizal fungi that help to create soil aggregate structure
   - Removed the plants that shielded the soil surface from the impact of raindrops and therefore sealed it off from further rain entering
   - Removed plants that were providing shade for the soil ecology
   - Destroyed the deep root structure that was holding the soil in place

3. *Can you name at least one place where dust storms still happen these days?*
   Answers could include: Oklahoma, Colorado, Kansas, Arizona, New Mexico, Texas, the Sahara Desert, the Gobi Desert, the planet Mars (!), and many other places . . .

4. *What sorts of problems are recent dust storms causing?*
   Answers could include: loss of topsoil on farms leading to decreased productivity; dust settles on snow, which then melts earlier due to loss of albedo effect (reducing water availability in spring and summer in certain areas that depend on glacial melt); eye and lung problems; accidents from poor visibility when driving; spread of disease from airbone organisms, and other issues.
5. *What do you think FDR meant when he said "The Nation that destroys its soils destroys itself?"*
   Answers will vary. The basic idea is that healthy topsoil is at the center of civilization: We depend on it for food, fiber, fuel, clean abundant water, human health, thriving economies, and stable infrastructure.
6. *Why is healthy, living, well-aggregated soil (the soil carbon sponge) so important?*
   Answers will vary. Participants should name at least two benefits of healthy soils, which might include things like: absorption and filtration of water; food production; soil's role as a carbon sink; and resilience against flooding, drought, runoff, wind and water erosion, and dust storms.

Large-Group Discussion

Go through the questions again as a large group. You may need to remind them what "well aggregated" means. Help direct participants to think back on the Flour vs. Bread exercise, asking such questions as:

› *Which kind of soil would be more likely to blow away in a dust storm—the soil that is like bread, or like flour?*

› *Which kind of soil would be more likely to have flooding—the soil that is like bread or like flour?*

Brainstorm

Have participants brainstorm all the things that healthy soil can do for a society and for other living things.

A scribe should write all the answers on the board.

Depending on participants' previous knowledge, answers may include: grow more food, fiber, and fuel; absorb water; filter water; store carbon; create stability for infrastructure (houses, roads, bridges, pipelines, etc.); grow food with increased nutrient density; create habitat for burrowing animals, birds, and insects, as well as liveable habitat for humans, plants, fungi, and microorganisms.

Wrap-Up

Have participants share the following:

› *What did you learn and how do you feel about it?*

› *What new questions did this leave you with?*

Ask them to write their questions on a sticky note or index card and give them to you. Use these questions to help guide your approach to future investigations.

WORKSHEET

"The Nation That Destroys Its Soil . . ."
A Letter from the President

My Dear Governor: February 26, 1937

The dust storms and floods of the last few years have underscored the importance of programs to control soil erosion. I need not emphasize to you the seriousness of the problem and the desirability of our taking effective action, as a Nation and in the several States, to conserve the soil as our basic asset. The Nation that destroys its soil destroys itself.

In the Act of Congress approved April 27, 1935 (Public No. 46 of the 74th Congress), the Federal Government, through the Soil Conservation Service of the Department of Agriculture, initiated a broad program for the control of soil erosion. Demonstration work has been undertaken but much remains to be done. The conduct of isolated demonstration projects cannot control erosion adequately. Such work can only point the way.

The problem is further complicated by the fact that the failure to control erosion on some lands (particularly if such eroding lands are situated strategically at the heads of valleys or watersheds) can cause a washing and blowing of soil onto other lands, and make the control of erosion anywhere in the valley or watershed all the more difficult. We are confronted with the fact that, for the problem to be adequately dealt with, the erodible land in every watershed must be brought under some form of control.

To supplement the Federal programs, and safeguard their results, State legislation is needed. At the request of representatives from a number of States, and in cooperation with them, the Department of Agriculture has prepared a standard form of suitable State legislation for this purpose, generally referred to as the Standard State Soil Conservation Districts Law. The Act provides for the organization of "soil conservation districts" as governmental subdivisions of the State to carry on projects for erosion control, and to enact into law land-use regulations concerning soil erosion after such regulations have been approved in a referendum. Such legislation is imperative to enable farmers to take the necessary cooperative action.

I am sending to you several copies of the Standard State Soil Conservation Districts Law, with a memorandum summarizing its basic provisions. I hope that you will see fit to make the adoption of legislation along the lines of the Standard Act part of the agricultural program for your State.

Very sincerely yours,
Franklin D. Roosevelt

Answer the following questions:

1. At the time that this letter was written, what do you think the structure of the soil was like in the areas that were suffering from dust storms and flooding—more like bread or flour? Were the soils well aggregated or poorly aggregated?

2. President Roosevelt seems to be implying that humans created this situation, and that humans can improve it. Many of the problematic areas used to be native grasslands (prairies, plains) that were plowed up and turned into farmland. What do you think that did to the structure of the soil, and to the living ecology of the soil. How do you think it contributed to the dust storms?

3. Can you name at least one place where dust storms still happen these days?

4. What sorts of problems are recent dust storms causing?

5. What do you think FDR meant when he wrote “The Nation that destroys its soils destroys itself?”

6. Why is healthy, living, well-aggregated soil (the soil carbon sponge) so important?

Citation: Franklin D. Roosevelt: “Letter to all State Governors on a Uniform Soil Conservation Law,” February 26, 1937. Online by Gerhard Peters and John T. Woolley, The American Presidency Project. http://www.presidency.ucsb.edu/ws/?pid=15373.

Resources

GUIDES FOR MONITORING CHANGES IN SOIL HEALTH

Field Methods for Monitoring Soil Health and Watershed Function (A companion to this teacher's manual. Step-by-step instructions for accurate and affordable monitoring, with several other activities, geared towards farmer, community, and classroom use.) http://soilcarboncoalition.org/learning/fieldmethods.pdf

Visual Soil Assessment Field Guide, FAO Version http://teca.fao.org/technology/visual-soil-assessment-vsa-field-guides

Visual Soil Assessment Field Guide, New Zealand Version (a little simpler than FAO version) www.landcareresearch.co.nz/publications/books/visual-soil-assessment-field-guide/download-field-guide

Comprehensive Assessment of Soil Health—the Cornell Framework http://soilhealth.cals.cornell.edu/training-manual/

RAINFALL SIMULATORS

Demonstrations by NRCS Soil Health Team These are the people who can arrange for a rainfall simulator demo at your school or community event. Scroll down on this webpage for Soil Health list. www.nrcs.usda.gov/wps/portal/nrcs/detail/national/contact/conservation/st/?cid=nrcsdev11_000223#soil

Purchase tabletop rainfall simulators (and larger versions) from the same manufacturer that the NRCS uses here. www.rainfallsimulator.com/simulators/ (They can be shared between schools if necessary.) Email them and ask for the curriculum they have developed to go along with them.

Video demo of plant litter effect on simulated rainfall (and an excellent project—made out of recycled materials—for classroom) https://youtu.be/og9cQKxlFnE

One of many examples of a homemade rainfall simulator: www.soils4teachers.org/files/lessons-and-activities/activities/lessonplan-erosion-model.pdf

USDA-NRCS SOIL HEALTH RESOURCES

NRCS National Soil Health Web Page
Some of the NRCS soil health resources are tucked into various regional websites, but this is a good starting place. www.nrcs.usda.gov/wps/portal/nrcs/main/national/soils/health/

NRCS Soil Health Update Newsletter
Lots of good stuff! To subscribe, email Ron.Nichols@wdc.usda.gov

Contact List for Soil Health Regional Specialists
Scroll down on this webpage for Soil Health list. www.nrcs.usda.gov/wps/portal/nrcs/detail/national/contact/conservation/st/?cid=nrcsdev11_000223#soil

Videos
Unlock the Secrets in the Soil, an excellent collection of short soil health videos. www.youtube.com/playlist?list=PL4J8PxoprpGbRi3gZ-fWN0dGD8bnnq3wM

"Behold our living soil" poster:
https://nrcspad.sc.egov.usda.gov/DistributionCenter/product.aspx?ProductID=1138

"The hope in healthy soil"poster:
https://nrcspad.sc.egov.usda.gov/DistributionCenter/product.aspx?ProductID=1139

"Unlock your farm's potential" brochure:
https://nrcspad.sc.egov.usda.gov/DistributionCenter/product.aspx?ProductID=1002

"Hope in healthy soil" video series DVD:
https://nrcspad.sc.egov.usda.gov/DistributionCenter/product.aspx?ProductID=1261

NRCS Soil Health Webinars
Managing for Soil Health When Growing Potatoes, with Brendon Rockey www.youtube.com/watch?v=GE S07e7ZqyA

Managing for Soil Health on an Organic Farm, with Klaas Martens www.youtube.com/watch?v=-73zTdon5Y4

Soil Erosion, an Historical Perspective, with David Montgomery www.youtube.com/watch?v=KcY4Kwa9fsk

Pest Management from an Ecological Perspective, with John Tooker www.youtube.com/watch?v=1X3HY2K-W0U

NRCS Short Profiles of Soil Health Leaders
Alan Mindemann (Oklahoma) print profile:
www.nrcs.usda.gov/wps/portal/nrcs/detail/ok/soils/health/?cid=stelprdb1260245

Video profile: www.youtube.com/watch?v=i1HWVXQrc3c

Jimmy Emmons (Oklahoma) print profile:
www.nrcs.usda.gov/wps/portal/nrcs/detail/ok/soils/health/?cid=stelprdb1260243

Video profile: www.youtube.com/watch?v=XlKk-OydwRM
(YouTube will link you to more of these profiles if you watch one.)

SOIL HEALTH PRINCIPLES

Videos
SARE National Conference on Cover Crops and Soil Health video collection www.youtube.com /playlist?list=PLWlltQ6Oy0zrdMXa9V7h2AFAacqtVb47n

Jay Fuhrer, Soil Health Workshop www.youtube.com/watch?v=umdFJ9mzjug

Ray Archuleta, It Starts with the Soil https://youtu.be/yExpSwpRkEs

Jill Clapperton, Soil Health Principles https://youtu.be/-z-r30mKP3c

Gabe Brown, Keys to Building Soil Health https://youtu.be/9yPjoh9YJMk

How Does Soil Health Translate to On-Farm Profits?
Part 1: www.youtube.com/watch?v=V8rIJrhY_HM
Part 2: https://youtu.be/xIVX1gZmSvg

How Do You Define a Healthy Soil? https://youtu.be/JIwjepz3eaY

Life in the Soil (a video on soil biology from Japan) www.youtube.com/watch?v=m20-t7bnsVw

Soil Food Web collected videos with Elaine Ingham www.youtube.com/playlist?list=PLdh7A7CwJ_djfIG1ecN8mCeOG4MsqcY4e

THE BIG PICTURE: BIOLOGY'S ESSENTIAL ROLE IN THE WATER CYCLE AND CLIMATE

Books

Water in Plain Sight: Hope for a Thirsty World, by Judith Schwartz

Water, a Natural History, by Alice Outwater

Water, Land and Climate—The Critical Connection: How We Can Rehydrate Landscapes Locally to Renew Climates Globally, by Jan Lambert

Videos

Restoring Water Cycles to Naturally Cool Climates with Walter Jehne https://youtu.be/K4ygsdHJjdI

Restoring Water Cycles Conference Videos (lots of wonderful presentations!) https://bio4climate.org/program-tufts-2015/

Articles

A Global Action Plan of Climate Recovery, by Jan Lambert and Michal Kravcik http://terranovavoice.tamera.org/2015/10/a-global-action-plan-of-climate-restoration/4074

PDFs

The Global Cooling Project http://www.theglobalcoolingproject.com/media/GC_Science_dossier7.pdf

Water for the Recovery of the Climate: A New Water Paradigm, by Michael Kravcik www.waterparadigm.org/download/Water_for_the_Recovery_of_the_Climate_A_New_Water_Paradigm.pdf

STORIES OF LAND RESTORATION PROJECTS AND THEIR LEADERS

Videos

The internet is full of videos of stories of how farmers and ranchers have adapted their management to make the most of the soil health principles. Here are just a few:

Brendon Rockey www.youtube.com/watch?v=GES07e7ZqyA

Colin Seis https://youtu.be/wVDJbajw03k?list=PLR0M4jry6bnFuBxhziLACZipvSJXl61mz

Todd McPeak www.youtube.com/watch?v=eefU_n3aa10

Carol Evans and Jon Griggs *Miracle in the Nevada Desert* (Exclusion Grazing and Beavers) https://youtu.be/lR7w9Tritj8

Gabe Brown www.youtube.com/watch?v=uUmIdq0D6-A

Dennis Hoyle www.youtube.com/watch?v=nCVzNuYOlDE

Allan Savory www.ted.com/talks/allan_savory_how_to_green_the_world_s_deserts_and_reverse_climate_change?language=en

Successful no-tillers www.youtube.com/watch?v=_mg-VDh4yB8

Video Collections
Videos of regenerative projects around the world, on a Google Map database: http://goo.gl/RbSjbV

Maps
A map of "soil health champions"(click on dots for profiles)
www.nacdnet.org/get-involved/soil-health-champions-network/

Articles and Interviews
Ian and Dianne Haggerty www.futuredirections.org.au/publication/natural-intelligence-farming-ian-dianne-haggerty/

Examples of Community Efforts
www.adelnews.com/news/20170803/gov-reynolds-discusses-1-percent-challenge-at-jonbar-ranch

www.albertafarmexpress.ca/2015/06/10/soil-carbon-challenge-coming-to-alberta/

www.manitobacooperator.ca/livestock/producers-explore-the-abcs-of-do-it-yourself-soil-health-tests/

www.practicalfarmers.org/

www.pinterest.com/OKSoilHealth/boards/

GENERAL, SOIL AND WATER

Videos
From Gray to Green Infrastructure in Urban Areas, with Scott Horsley https://youtu.be/mjdCecOLx9I

Managing Australian Rangelands for Drought, with Dr. Christine Jones https://youtu.be/salOtdeYE6k?list=PLKhvx4ucULfOf1VlpYFb0wpwQCgxkQD6p

Collection of soil and water related videos www.pinterest.com/defendingbeef/videos-water-related-issues/

Articles
A collection of soil-and-water related articles www.pinterest.com/defendingbeef/articles-water-related-issues/

Water holding capacity of soils (see second half of article) www.nrdc.org/sites/default/files/climate-ready-soil-appendix.pdf

Various
John Liu's collected papers and films http://knaw.academia.edu/JohnDLiu/

This is just a sample listing highlighting some of the wonderful resources that are available. I would love to hear additional suggestions of books, articles, videos, additional curricula etc. that you have found most useful. You can send suggestions to: landlisteners@gmail.com.

Credit Abigail Feldman

About the Author

DIDI PERSHOUSE is a cross-pollinator, helping to connect the dots between soil health and human health. She is the author of *The Ecology of Care: Medicine, Agriculture, Money, and the Quiet Power of Human and Microbial Communities*. As the founder of the Center for Sustainable Medicine, she developed a practice and theoretical framework for systems-based ecological medicine—restoring health to people as well as to the social and ecological systems around them.

After twenty-two years of clinical work with patients, she is now working with the nonprofit Soil Carbon Coalition and other organizations on a large-scale citizen-science program that engages schools, conservation districts, farmers, and the public in understanding the intersections between healthy soil, water, public health, and climate resiliency.

To contact the author or to schedule a workshop
for your school district or community:
email **landlisteners@gmail.com**
or visit **www.didipershouse.com**

For the most recent version of this manual and more resources, visit
www.soilcarboncoalition.org/learn

Soil Health Principles

Use plant diversity to increase diversity in the soil.

Manage soils more by disturbing them less.

Keep plants growing throughout the year to feed the soil.

Keep the soil covered as much as possible.

United States Department of Agriculture
Southern Plains Climate Hub

United States Department of Agriculture
Natural Resources Conservation Service

Dixon Water Foundation

REDLANDS COMMUNITY COLLEGE

soil Carbon coalition